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A monthly survey by the U. S. National Committee for the International Geophysical Year. Established by and part of the National Academy of Sciences, the Committee is responsible for the U. S. International Geophysical Year program in which several hundred American scientists are participating and many public and private institutions are cooperating.

Total Solar Eclipse: October 12, 1958

Since 1836 scientists have been making physical observations of the solar spectrum during eclipses, especially of the spectrum of the corona, the outer atmosphere of the sun (see Fig. 1). Invention of the coronagraph by Lyot in 1930 made it possible to observe some aspects of the corona without waiting for an eclipse; but the "artificial eclipse" of the coronagraph does not completely eliminate the scattered light from the sun's disk. In a total eclipse, radiation from the solar disk is blocked by the moon; for a short period, therefore, only radiation from the corona reaches an observer in the path of totality. Thus, an actual solar eclipse provides a unique opportunity to study characteristics of the sun and of solar-terrestrial relationships which cannot be duplicated in a laboratory.

Studies of the distribution of different radiation wavelengths on the sun's disk and the effects of specific wavelengths on the ionosphere are made possible during an eclipse since the moon acts as a shutter, successively blocking off portions of the disk. This effect cannot be duplicated by the coronagraph.

The total eclipse of the sun due on October 12, 1958, occurs at an extremely opportune time for solar studies; the solar physics studies of the IGY will provide an abundance of data on the sun for long periods before and after the eclipse. It also occurs near a period of maximum solar activity, the most active solar maximum in recorded history. September and October 1957, on the basis of preliminary reports, had the highest sunspot numbers ever recorded. At the time of the eclipse the sun should still be very active.

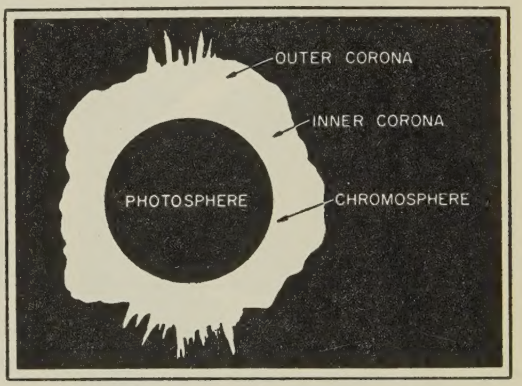

Fig. 1. *Solar Regions. The visible disk of the sun is called the* photosphere (*sphere of light*). *Above the photosphere is the* chromosphere (*sphere of color*). *The portion of the chromosphere immediately above the photosphere is sometimes called the "reversing layer." Above the chromosphere is the* corona (*crown*), *which is divided into* inner corona *and* outer corona, *or* white corona. *The boundaries between regions are not definite, one region merging imperceptibly into another.*

Observational Program: The Technical Panel on Solar Activity of the US National Committee for the IGY is taking full advantage of this favorable situation and has organized an extremely broad observational program. Six teams of US scientists will travel

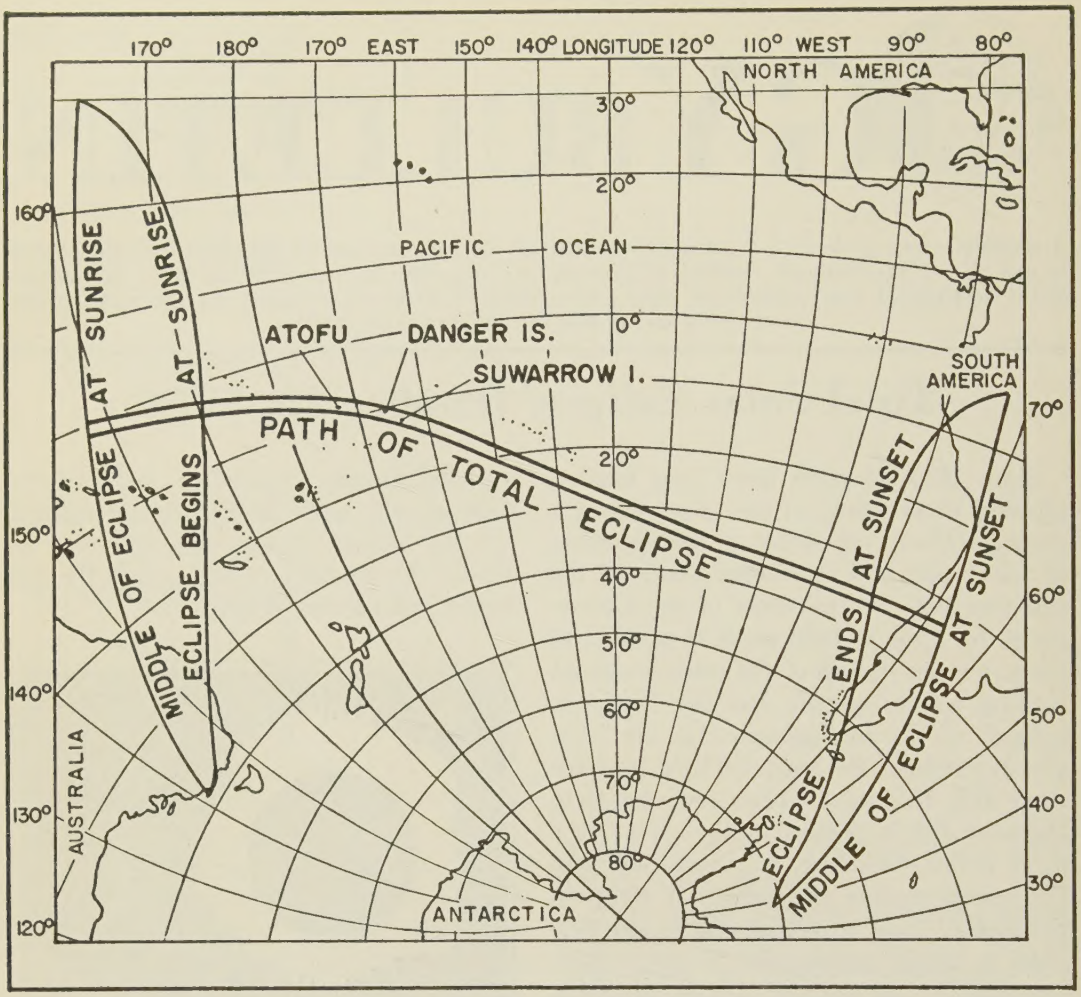

Fig. 2. *Path of Totality of Eclipse of October 12, 1958, and Location of Observation Sites.*

to the Danger Islands, an atoll in the South Pacific also known as Pukapuka after the largest island in the group; there they will mount four ground-based optical experiments, one rocket experiment, and one ground-based electronic experiment. Preparations for these experiments have been underway since before the beginning of the IGY in July 1957.

Existing weather records indicate a 40% chance that clouds will obscure the sun during the critical period of totality, but cloud conditions will impede only the optical experiments. No matter what the weather, the electronic experiment and the rocket observations will go forward and should obtain extremely valuable data on solar radiation and associated ionospheric effects.

The institutions participating in the expedition are the Naval Research Laboratory (NRL), the Central Radio Propagation Laboratory (CRPL) of the National Bureau of Standards, the University of Wisconsin, the California Academy of Sciences, the US Naval Radiological Defense Laboratory, the Sacramento Peak Observatory, and the High Altitude Observatory.

Logistic Problems: The main problem facing the planners of the expedition has been the selection of a suitable piece of land on which to erect the observational instruments. The path of totality begins at sunrise approximately on the equator at about 158°E and ends at sunset at a point

inland from Santiago, Chile (see Fig. 2). The path misses all the large Pacific Islands, and observations from Chile would be impractical because of the low altitude of the sun at the time of eclipse. The only dry land from which observations would be profitable are coral islands too small to support a large expedition comfortably.

The logistic problem has been solved with the help of the Navy, which is furnishing the USS *Thomaston*, a Landing Ship Dock (LSD), to serve as transportation, floating hotel, and warehouse for the period the expedition is at the Danger Islands site. The expedition plans to arrive at the Danger Islands about September 1 and leave on November 1. Except for a period of one week during which the *Thomaston* will travel to Samoa to refuel, all personnel will live aboard the ship. They will be ferried by boat and helicopter to and from the observational site on the most southerly island of the group, Motu Koe.

Since the *Thomaston* is much too large to enter the lagoon of the atoll by the only passage, and anchorage is not possible outside the atoll, the LSD must steam back and forth in the open ocean two or three miles from the outer reefs to maintain position.

Electronic Experiments

Two electronic experiments, one by the Naval Research Laboratory and one by the CRPL, National Bureau of Standards, will observe ionizing sources on the sun and the resultant ionization in the earth's atmosphere.

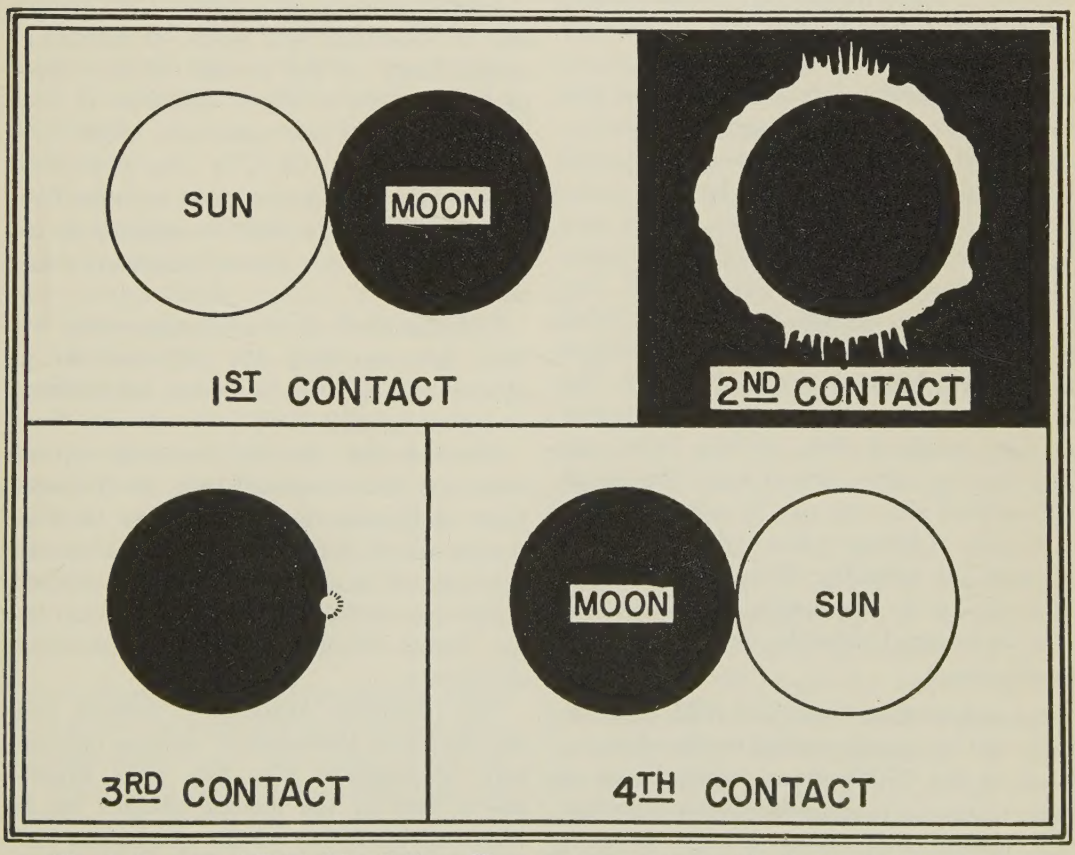

Fig. 3. *Progress of Total Solar Eclipse. The moon appears to overtake the sun in their passage across the sky: (a) The moon touches the edge of the sun (first contact); (b) The moon covers the sun and the corona becomes visible (second contact); (c) The sun reappears (third contact); (d) The moon passes the sun (fourth contact).*

Ionizing Sources: The Naval Research Laboratory plans to study the distribution of ionizing sources on the sun's disk and in the corona by direct measurement from rockets. NRL plans to fire a series of 6 to 8 rockets during the eclipse, two during the period of totality and the rest during the partial eclipse before and after totality. Each rocket will be equipped with detectors for soft X-rays (50 Å), harder X-rays (8–20 Å or 1–7 Å), and Lyman-alpha ultraviolet radiation (1216 Å). The rockets will be the Nike-Asp system, fired from shipboard approximately 10 miles from Pukapuka. Data recorded during the rocket flights will be telemetered to receivers aboard the *Thomaston*.

Each rocket will be in flight for approximately seven to eight minutes—about five minutes of which will be above the absorbing atmosphere. Totality will last about four minutes. As the most interesting data is expected at that time, it is planned to have two rockets in the air throughout totality. Aboard ship, data from the two rockets will be recorded simultaneously by two independent telemetering stations. These two rockets will be launched in quick succession just before second contact (see Fig. 3). Between first and second and between third and fourth contacts, rockets will be launched so as to bracket active coronal regions. The first in each pair will measure the solar flux as the occulting disk of the moon approaches an active coronal spot; the second will be fired after the spot is covered.

A series of firings to test and, if necessary, improve the reliability of the rocket system is scheduled for the spring of 1958 at San Nicolas Island, California, on the Pt. Mugu missile range.

Ionospheric Soundings: The NRL observations will be complemented by the observations of the CRPL group, which hopes to obtain data on heights, ionization densities, and critical frequencies of the different ionospheric layers by use of a modified vertical-incidence sounder. The sounder will operate from Motu Koe Island during the eclipse and for a suitable period before and after. Using pulses of radio energy, this equipment determines the heights and ionization densities of the ionospheric layers.

Because these layers are ionized by solar ultraviolet and X-radiation, a solar eclipse causes a marked decrease in ionospheric density. Correlation of the radiation data gathered by the rockets and the ionospheric data gathered by the sounder should give much information about the changes of ionospheric structure with changes in solar radiation. These two experiments can be carried on regardless of the amount of cloud cover.

Optical Experiments

Interferometry: A group from the University of Wisconsin will make an interferometric study of the coronal emission-line profiles and the absolute intensities of two lines of the coronal spectrum, λ5303 (Fe XIV) and λ5694 (Ca XV). The green line λ5303 is the strongest coronal emission line and the yellow line λ5694 is expected to be at its brightest at a time of maximum solar activity.

Either or both of two techniques may be used for recording the information: a photomultiplier with a sweep mechanism, or a photographic plate.

Most of the essential scientific equipment has been borrowed from the Department of Physics of the University of Wisconsin, where it is used in research on the structure of atomic spectral lines. Other equipment for the expedition was loaned by the Yerkes Observatory of the University of Chicago.

The California Academy of Science and the US Naval Radiological Defense Laboratory investigators plan two joint experiments, one on the moving shadow bands which appear in the earth's atmosphere just before second contact and just after third contact, and one on the polarization of the outer corona.

Shadow Bands: Measurements will be made of shadow-band phenomena by recording the output of photronic cells on a Helland Oscillograph Recorder during the period just prior to second contact and just after third contact. An array of 8 or 10 cells will be set up in some pattern as yet not wholly decided upon, but likely in the form of a cross, spaced at varying distances in an effort to obtain the direction, speed, and wavelength of the shadow bands. Each cell, measuring about 2 by 6 inches, will be mounted on a stake driven into the ground and connected to the recorder by a shielded cable.

Since it is generally believed that the shadow-band phenomena are produced by atmospheric discontinuities, it would be desirable to correlate the motions of the shadow bands with velocity and direction of winds aloft. It is hoped that NRL will be able to provide wind data by observations of balloons released sometime during the hour or two just prior to or just after eclipse time.

Polarization of Corona: A camera now under construction will employ a 20-inch focal length lens for obtaining photographs of the outer corona (white corona) in light polarized with respect to radial directions. A shutter consisting of a rotating sector will be used, and a sheet of polaroid will be rotated with the shutter. By an independent rotary adjustment of the polaroid with respect to the shutter, use can be made of the light polarized at various angles with respect to a radius. By use of filters, further restriction of the light can be obtained; this may provide added information regarding the polarization of the corona.

Flash Spectrum: A joint experiment of the Sacramento Peak Observatory and the High Altitude Observatory, sponsored by the US Air Force, will attempt to photograph the "flash spectrum" of the chromosphere. At the instant of totality the dark lines of the Fraunhofer spectrum appear to change suddenly to bright lines of chromospheric emission. The phenomenon lasts only a short time, perhaps 25 seconds at second contact and 25 seconds at third contact for the strongest lines, and the weakest lines may be observable for only 3 to 4 seconds in all. But observation of the flash spectrum yields information on structure and composition of the chromosphere which can be obtained in no other way.

In order to obtain the desired information on the corona, height resolution of the order of 100 km is necessary. This cannot be accomplished with a coronagraph, because errors of seeing in a man-produced "eclipse" blur height discrimination of distances far greater than 100 km. When the eclipse is produced outside the atmosphere, however, such height discrimination becomes possible—provided photographs can be taken fast enough. To do this, a spectrogram must be exposed every 0.3 second.

The equipment consists basically of a triple spectrograph to cover three spectral ranges: (1) 3300 Å to 6600 Å for the ultraviolet unit; (2) 3600 Å to 4900 Å in the visible; and (3) 5000 Å to 9300 Å in the infrared. Dispersions will be 5½ Å/mm in the ultraviolet and infrared and 2 Å/mm in the visible. The spectrographs will be fed by a single coelostat (a rotating mirror which follows the sun's movement). Each spectrograph will have a double camera unit, so that the speed requirement for a single camera will be one frame each 0.6 sec. Exposure is to be 0.2 sec, with film transport and shutter action to be accomplished in 0.4 sec. The size of each frame is 26″ by 7″.

Each frame will contain three separate spectra differing from each other in terms of intensity of the incident light in the ratio of 1 to 20 to 400. Also to be included on each frame will be the image of a step wedge illuminated by a lamp, to furnish a standard for comparison of the intensity of the spectra. Finally, there will be a serial number on each frame. The serial number will be used to identify the frame, so that it can be matched up with additional data (length of exposure, time, and so forth) to be imprinted on a multi-channel recorder. Ab-

solute calibration will be provided by exposing spectra of the sun itself through the same optical system, both before and after the eclipse.

Expeditions by Other Countries

In addition to the US-IGY effort, at least two expeditions from other countries will conduct careful observations of the eclipse. The Japanese plan an extensive series of observations from a base on Suwarrow (Suvarov) Island, several hundred miles from the Danger Islands. The USSR has indicated that it will send an expedition but has not designated a site. New Zealand will establish a base at Atofu.

The Visual Auroral Program

Much of the following material has been adapted from a manual prepared by C. W. Gartlein and D. S. Kimball, Cornell University, for use in the IGY visual auroral program.

Auroras are the visible manifestation, in the earth's atmosphere, of a group of phenomena resulting from disturbances in the sun's interior and surface layers. They mark the paths within the atmosphere of the streams of solar particles ejected by eruptions on the sun. Hence, studies of the forms and global distribution of auroral displays do much to define these paths, as well as to determine the energies of the particles, the way they are trapped by the

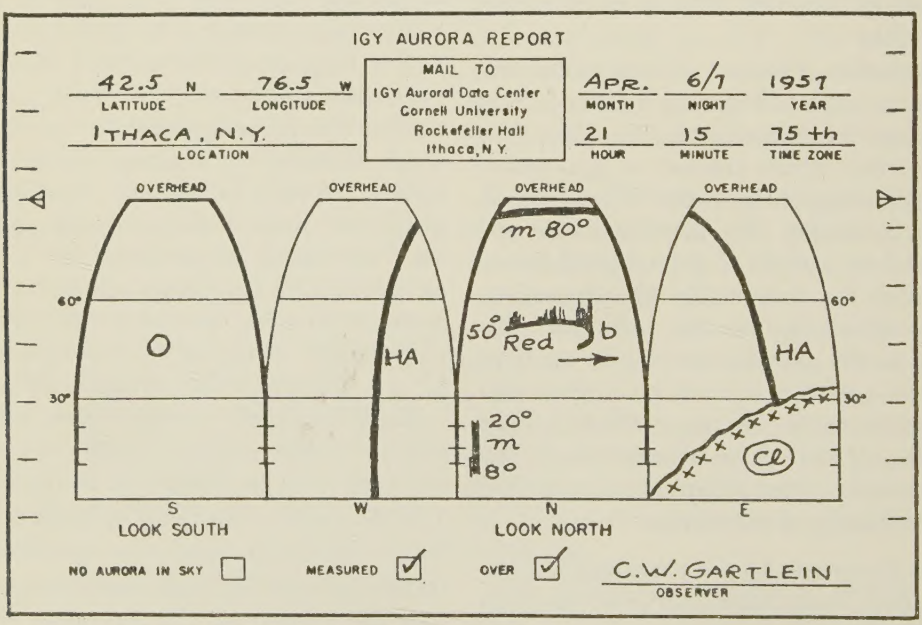

Fig. 4. *Sample Auroral Report on Standard Graphic Card. The report, for 9:15 pm EST, shows a medium-intensity homogeneous arc (HA) extending from the western horizon to a bank of clouds 30° above the eastern horizon. As no color is indicated, the arc is either colorless or yellow-green. The HA reaches an angular height of 80° from the northern horizon—almost to the observer's zenith. To the north and at a height of 50° is a bright, eastward-drifting rayed arc (RA). Its lower margin is red. Rays (R) of medium intensity appear toward the northwest. They are vertical and extend from 8° to 20° above the horizon. No aurora appeared in the south. More elaborate sketches, or simple letter symbols, may also be used on these cards.*

earth's magnetic field, and possibly their acceleration within the atmosphere.

While auroras occur most frequently in high latitude belts circling the geomagnetic poles, auroras visible in middle and low latitudes, and especially in the tropics, are of special scientific interest. During the IGY, auroral displays in these regions in the northern hemisphere are being studied intensively by a large number of visual observers throughout the US and Canada.

Thousands of visual observations of auroras have been made in the past but systematic analysis in terms of form, time, location, height, extent, intensity, movement, etc. has been lacking. The IGY Visual Observation Program is designed to correct these deficiencies.

North American IGY Visual Observation Program

In the integrated, cooperative North American IGY program for visual auroral observation, personnel at meteorological stations of Canada and the United States are supplying much of the data. As other duties permit these participants to observe for short intervals only, many volunteer observers have been asked to assist. The volunteers are able to make more continuous and detailed observations than time allows the meteorological observers. Airline and ship crews are also assisting in the program.

In past visual observation programs, many observers have supplemented their written reports with sketches to show details of the arrangement of auroral shapes, structures, and movements. In one program the entire report was made in sketch or graphic form. This method was so satisfactory that it is used as the basis of the present volunteer program.

Reports are made graphically on a simple card which carries a diagram consisting of four quadrants representing the dome of the sky as seen facing south, west, north, and east (see Fig. 4). Completed reports are mailed to the IGY Auroral Data Center at Cornell University, Ithaca, New York.

Auroral Forms and Sequence

Auroras occur in a number of characteristic forms (Fig. 5), for which simple graphic representations have been standardized to facilitate reporting.

The various auroral forms usually occur in a specific sequence during a particular display, although the entire sequence may

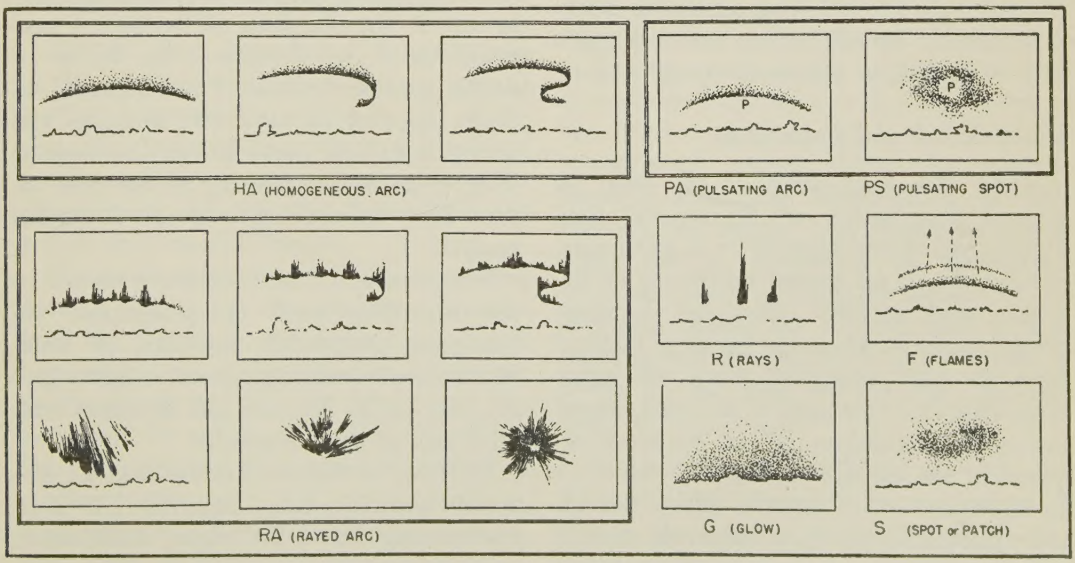

Fig. 5. *Sketches of Auroral Forms.*

not necessarily appear. Near the beginning of a display, predominantly homogeneous forms appear, glows (G) and homogeneous arcs (HA). There is little motion. A glow seen early in a display may actually be the upper part of a distant aurora whose lower border lies just below the horizon. The aurora may subsequently rise, revealing itself as an arc or a band. This may be repeated more than once.

Rayed forms showing considerable motion are characteristic of the second phase of the display. This phase, consisting of rayed arcs (RA), rays (R), and sometimes flames (F), is the main part of the display. It is accompanied by increased luminosity and the appearance of distinctive colors.

The declining phase of the auroral display is characterized by indistinct patches of luminosity, sometimes spotty (S) and with scattered, diffused rays; glows, which may persist for several hours; pulsating forms (P); and occasionally rays or flames.

Changes in auroral forms during a display are believed to be associated with changes in the earth's magnetic field, earth currents, and ionosphere. Of particular interest are changes of one form into another, such as a homogeneous arc into a rayed arc; the appearance of a new form, such as a homogeneous arc following a glow, or a second arc; and the appearance and disappearance of flaming or pulsating auroral forms.

Observation and Reporting

Time: The best times of the year for auroral observations are Spring and Fall. During March and September, in particular, auroras are at an annual maximum of frequency and intensity. These are the equinoctial periods, when the earth is farthest from the sun's equatorial plane and hence more directly in the path of material ejected during solar eruptions. (These are most frequent in the middle latitudes of the sun.) In addition to this seasonal effect, the 11-year sunspot cycle also influences auroral activity. After the cycle starts, the greatest solar activity, which means many solar eruptions, occurs in middle solar latitudes. Later in the cycle, although eruptive activity takes place nearer the sun's equator, such activity diminishes considerably. As a result of the combined effects of these seasonal and cyclical factors, auroral activity reaches a peak about a year after the sunspot maximum.

Although auroras are usually more frequent during the periods March–April and August–September, observation is not restricted to these months. Northern observers make observations each possible night throughout the year. A report of no aurora on a clear night may be as important statistically as the record of a brilliant display, particularly during times of Alerts and Special World Intervals (SWI) declared by the IGY World Warning Agency (WWA). (*Bulletin No. 5*, November 1957, contains an outline of the IGY Special World Days Program for coordinated intensification of upper atmosphere observations during times of heightened solar activity.) In latitudes below about 40°N, where auroras are rare, observations are made primarily on nights when geomagnetic disturbances are expected, i.e., during Alerts and SWI.

Reporting auroral forms: The auroral forms are indicated on the reporting card by use of the standard abbreviations indicated above, by sketches (Fig. 5), or by simple graphic symbols. The horizontal division lines at 30° and 60°, and the tick marks at 21°, 14°, and 10° on the diagram (Fig. 4) guide the plotting of the observation. They are also essential aids in further analysis.

The location of the observer is shown on the reporting card by geographic coordinates, geographic location, or both. Airline crews making auroral reports give the location by distance and direction from some nearby control point.

The date of the observation is given as a double calendar date, e.g., Jul 1/2 1957, representing the entire night, both before and after midnight, regardless of the exact time the observation was made. Although

regular observations are made as nearly as possible every quarter hour, the exact time of an observation is recorded to the nearest minute on a 24-hour basis, e.g., 23^h42^mEST or 2342EST.

Visibility: Clouds, haze, fog, twilight, moonlight, and other factors affecting light conditions in the sky determine the visibility of a given aurora. They also affect it indirectly by changing the brightness of distant city glow. Such conditions are recorded in the diagram by circled abbreviations.

Location: When the lower border of an auroral form, generally about 100 km (62 mi) above the earth's surface, is seen 60° above the horizon, the form is located over a point on the surface about 30 mi from the observer. Thus, the upper ⅓ of the quadrants on the diagram contain reports of auroras occurring within a radius of approximately 30 mi of the observer's location. Similarly, the 30° lines define a circle with a radius of about 90 mi centered on the observer. The short tick marks represent lower elevations above the horizon and define circles of greater radii. In this way, a complicated mathematical transformation is effected in a simple, graphic manner with the required precision.

Heights of auroral forms: Measurement of the angular height of an auroral form is made by visual estimate or by use of devices for determining vertical angles, such as theodolites, air navigation octants, inclinometers, and alidades. Forms near the zenith are of special interest.

Observers possessing suitable measuring devices determine the angular elevation from the horizon to the lower edge of each form whenever possible. Angular elevations to the top of isolated ray forms are also measured. To aid the individual observer in the measurement of angular elevations, a simple inclinometer has been designed. Though light enough to be held in the hand, this instrument can give measurements accurate to within 1°.

A program using a more complicated and more precise instrument, the alidade, has been designed for groups of observers who can work consecutively during a major portion of the night. Participants in this program report the same data as the individual observers, but confine their observations largely to the meridian. Measurements are plotted on a card designed to fit into a slot on the instrument.

Intensity: The intensity of an auroral display is indicated by writing standard letter symbols next to the auroral form on the reporting card. A weak, or faint, aurora is approximately equivalent in brightness to the milky way; auroras with the brightness of a moonlit cirrus cloud are considered medium. Bright auroras have about the intensity of moonlit cumulus clouds, and very bright displays are much brighter than this.

Motions: Auroras commonly display characteristic motions. Drift motions—slow, steady, east-west motions that appear to vary systematically during the night—are observed as slow changes in position of an entire form. Drift is not immediately apparent as the forms normally move only a few degrees per minute. On the reporting card, the drift is shown by a horizontal arrow pointing in the direction of movement.

The expansion of the entire auroral zone is evidenced by a slow southward motion of the whole aurora, in which the forms rise progressively higher above the northern horizon, sometimes approaching or even crossing the zenith. This expansion can be recognized by comparing an observation with one made 15 minutes earlier. In the declining phase, the auroral zone is contracting and the motion is to the north, or lower in the sky toward the northern horizon.

Colors: Auroras are often of such low intensity that colors are not apparent. If this is the case, or when the color is the usual yellowish-green, the observer makes no report on color. Other colors, usually red,

blue, or violet-grey are rare—occurring only about $\frac{1}{20}$th as frequently as the yellow-green—but significant. These are reported. Red may appear extensively in a display, especially in low latitudes. (An aurora that occurred on February 10/11, 1958, and was seen as far south as Cuba, was reported by many observers as red in color.) The red color may appear at the lower borders of arcs or bands, at the tops of rays, or as diffuse clouds.

Optical devices: A number of simple optical aids are used by visual observers. Color filters help to distinguish auroral forms and colors as well as screening out moonlight and scattered city light. Still, time-lapse, and color photography are used by many observers to provide permanent visible records of auroral events. Pairs of photographs taken of the same aurora from different ground locations permit accurate height determinations.

Status of the Program

By January 1958 about 430 active observers were taking part in the visual auroral program. Approximately 130 US Weather Bureau stations, most of them reporting hourly, and 30 airline pilots are participating. The IGY Auroral Data Center is receiving about 5000 reporting cards per month from the Weather Bureau and roughly 6000 per month from volunteer observers. To date, more than 36,000 auroral reports and more than 350,000 reports of no aurora have reached the Data Center. More than 1200 cards were received on the aurora of February 10/11, 1958. This extensive aurora was, therefore, the world's most widely observed display up to that time.

Based largely on data received from participants in the visual observation program, synoptic maps are being prepared on a 15-minute basis for every aurora reported in the United States (see Fig. 6). The maps show the overhead location of the aurora and its shapes, intensity, changes, colors, and movement. Data accumulated during Special World Days and Special World Intervals are making it possible to construct similar maps of the distribution of

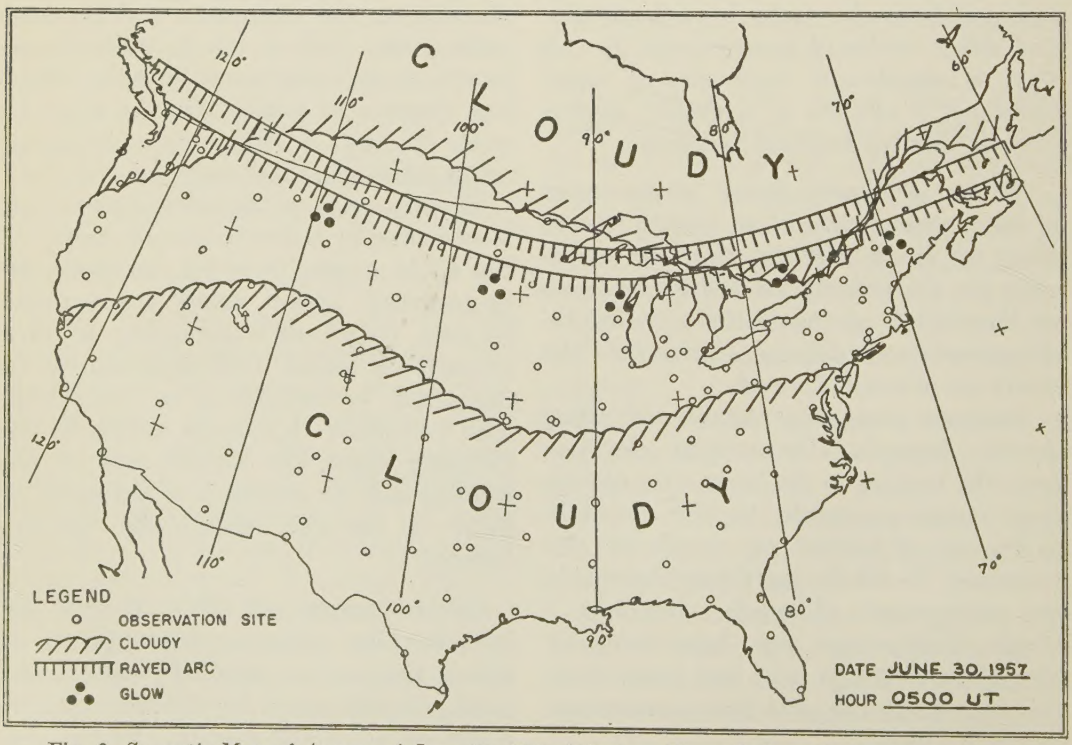

Fig. 6. *Synoptic Map of Aurora of June 30, 1957, Nineteen Hours Before the Official Beginning of IGY. The map was compiled at the IGY Auroral Data Center, Cornell University, Ithaca, N. Y.*

auroras over the entire globe for these periods of increased auroral activity. The maps prepared are microfilmed for international exchange.

Early Results: A number of interesting auroral features have already been reported in the Visual Observer Program. In large auroras, displacements of the coronas have been observed. Coronas, or radiant crowns, are formed when rays appear to converge (a perspective effect) as they approach the magnetic zenith—the position in the sky toward which the magnetic dip needle points.

Four months of Weather Bureau observations indicate that auroral motions are greatest at about midnight, and are predominantly from west to east.

The aurora is probably visible over the entire night side of the earth; continuous arcs have been observed for more than 2000 miles, and simultaneous auroral events have been observed from the English Channel to Ohio.

Arctic Sea-Ice Studies

This report is based on material supplied by Norbert Untersteiner, Department of Meteorology and Climatology, University of Washington.

As part of the IGY program for study of the earth's heat and water budget (described in *Bulletin No. 2, August 1957*) investigations of the physics of sea ice and the heat and moisture exchanges across the ice-atmosphere and ice-ocean interfaces are being conducted on IGY Drifting Station A in the Arctic Ocean ice pack (see Fig. 7).

The primary objective of these studies is to obtain data on the relative influence of the transfer of radiative heat and of latent heat on the mass budget of sea ice. (Radiative heat is heat released by emission or absorption of electromagnetic waves; latent heat is heat released by the change of state of water, i.e., melting, freezing, evaporation, condensation, etc.) Transfer of heat between the ocean and the atmosphere by conduction through the ice is also being studied. The investigations are scheduled to be carried out over a period of at least 12 months. This report covers some of the preliminary results of work done during the period June–September 1957.

The work is being carried out by the University of Washington Department of Meteorology and Climatology. IGY Drifting Station A, on a seven-foot-thick ice floe with an area of about four square miles, was established and is supported and maintained with the help of the US Air Force. It was first occupied on April 5, 1957; its position on April 24, 1958, was 84°N, 152°W, about 375 mi from the North Pole

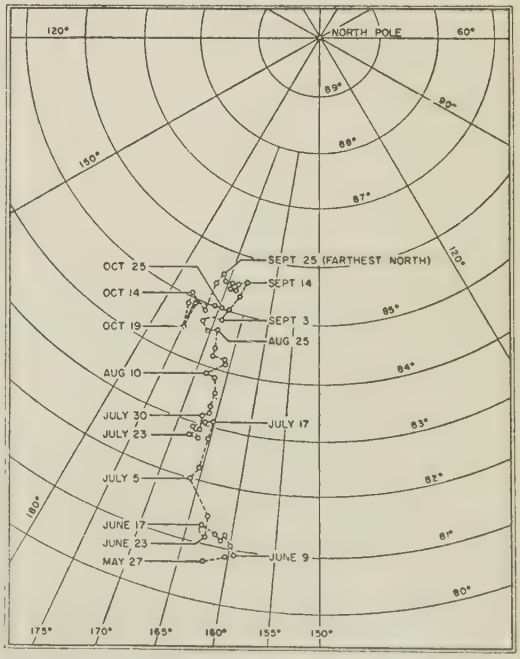

Fig. 7. *Movement of US-IGY Drifting Station A in Arctic Ocean, May 27–October 25, 1957.*

and 925 mi north of Barrow, Alaska. All equipment was installed on the drifting station by mid-June, well before the onset of melting.

Drifting stations are advantageous for studying the earth's thermal budget and other meteorological factors since they are distant from land masses and are surrounded by a uniform surface, conditions that make the data accumulated representative of a large area.

Techniques of Observation

Radiation: A radiometer is used to measure separately the total amounts of both incoming and reflected radiation; solarimeters measure the incoming and reflected short-wave radiation.

Temperature: Air temperatures are measured at 25, 50, and 100 cm above the ice by use of copper-constantan thermocouples. Thermocouples installed at three sites also measure temperatures at four levels in the ice. Ocean temperatures at a depth of three meters below the ice are obtained by use of additional thermocouples. A 16-point recorder is employed when continuous records are required.

Wind: The wind profile is obtained 20, 40, 80, and 160 cm above the ice surface whenever general weather or surface conditions are changing.

Evaporation: Estimates of evaporation are made by periodically weighing ice or snow collected in plexiglass pans buried level with the ice surface. This technique is feasible only when precipitation and drifting snow are absent.

Mass Budget Measurements: Direct evaluation of the change in total mass of the ice pack has been difficult. Measurement of ablation (loss of snow or ice, primarily by melting) at 16 localities appears to have established satisfactorily the loss of solid ice. But the initial amounts of snowfall and of melt beneath the cover of snow and slush could only be estimated. Too many observation sites would have been needed for an adequate measure owing to the collection of water in many depressions on the irregular surface of the floe, and to the extent of natural and artificial drainage.

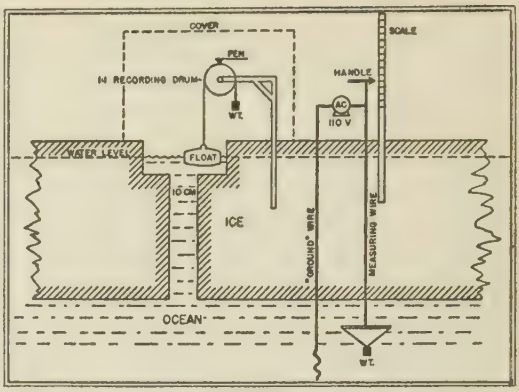

Fig. 8. *Water-Level Recorder (left) and Instrument for Measuring Accretion and Ablation at the Bottom of the Ice (right). The recorder utilizes a float placed in sea water which partially fills a pit; at the bottom of the pit a hole is drilled through the ice to the sea. A pen records water-level fluctuations on a drum.*

Mass changes at the ice bottom are measured by the other device. It consists of a measuring wire extended vertically through the ice; a cross bar is attached at the bottom. The wire, normally frozen into the ice, can be released by sending a current through a circuit completed by a second wire reaching the ocean. The measuring wire can then be pulled up until the cross bar touches the ice bottom. Readings are made on a scale fixed in the ice.

In anticipation of these difficulties, a water-level recorder was set up to determine relative height changes between the water surface and a fixed level in the ice (Fig. 8). This indicated how far the ice floe rose after natural and artificial drainage and how much lower in the sea it floated under a mantle of new snow. These records, however, do not distinguish mass changes at the surface from those at the bottom of the ice. Moreover, the instrument is only $\frac{1}{9}$ as sensitive to ablation and accretion at the ice bottom as it is to these factors at the ice surface. In order to make the bottom measurements more accurately, another instrument was devised (also shown in Fig. 8). In addition, total thickness can be determined with

greater ease and accuracy using this device than by drilling to the bottom of the floe.

Additional Measurements: Measurements are also made of the thickness and density of the ice, chlorine content (or salinity) of the sea water, and surface temperature (with thermocouples).

Accumulation and Ablation at the Surface of the Ice

An estimated 40 cm of snow, with a density of 0.3–0.4 gm/ cm^3, accumulated during the winter and spring before melting began. Melting, which started in mid-June, was rapid owing to the low albedo (percentage of visible light reflected by a natural surface) of water and water-saturated snow. The snow cover had almost completely disappeared by July 8. Stakes were then emplaced for measurement of ice ablation, which averaged about one cm/day during the main ablation period, July 9–24.

Following the ablation period, a blanket of new snow began to develop, occasionally interrupted by brief melting periods. After August 8, however, accumulation increased steadily. The new snow cover reached a depth of approximately 20 cm by the end of September. Figure 9 summarizes the results of these accumulation-ablation observations during the summer of 1957 and Figure 10 portrays them diagrammatically.

During early July, the melt water ponded on the surface reached its greatest extent, covering approximately 30% of the total surface area. On July 3, when the water-level recorder was installed, the temperature of the central portion of the ice (at depths of 150–200 cm) was −3.5°C. Ice at these depths was essentially impermeable to melt water, and run-off over the edges of the floe was negligible. Therefore, virtually all melt water that had collected by early July still remained on the surface of the floe. By mid-August, holes had been melted through the ice, allowing the water to drain off and the floe to rise higher in the sea.

Water Level Records: As shown by water-

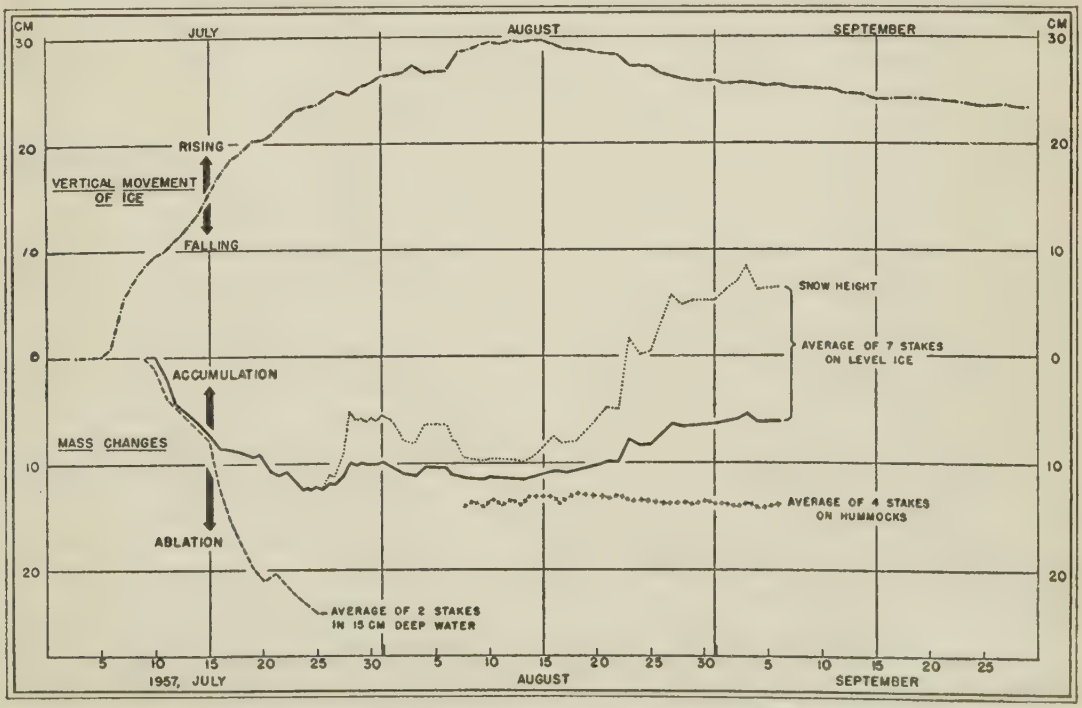

Fig. 9. *Graph of Mass Changes and Vertical Movement of the Ice Floe During the Summer of 1957.*

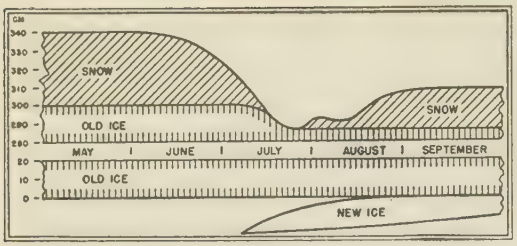

Fig. 10. *Schematic Diagram of Mass Changes, May–September 1957.*

level records, the ice floe rose a maximum of 29.6 cm from June through August 15, 1957. This is equivalent to a loss of 32.8 cm of ice. As determined by ablation measurements, on the other hand, the total ice loss, including melting of the spring accumulation of snow, was 26.5 cm. The difference of 6.3 cm may be accounted for by assuming a greater ablation in melt-water ponds, which covered 15–30% of the surface area for a three-week period. (The dashed line in Figure 9 indicates that ablation beneath 15 cm of water is approximately twice as great as that of bare ice.)

It is not possible to use the water-level records for ablation determinations over short periods. However, they appear to give reliable values for total ablation. A further practical characteristic of these records is the fact that they show runoff, or the amount of ice actually removed from the surface, rather than melting.

Stake Readings: For the period July 25–September 6, stake readings indicate a total accumulation of 3.4 cm of ice. The ice accumulation shown by the water-level recorder for the same period was 2.4 cm. Again the stake readings are considered less reliable as they represent level-ice conditions and do not account for the effects of the numerous hummocks or mounds. No appreciable accumulation was shown during this period by four stakes set on hummocks, which were about one meter high and 15 meters across.

Accretion and Ablation at the Bottom of the Ice:

On July 21, drilling revealed a newly-formed ice layer 1–3 cm thick beneath the pack ice. A layer of fresh water or slushy ice, with a temperature of 0°C and of varying thickness, separated it from the previous ice bottom. Further drilling showed that the distribution of this fresh-water layer was related to the topography of the underside of the pack ice. Pools formed under places where the ice was thin (about 250 cm) and were absent beneath hummocks and thick ice (greater than 300 cm).

Early in its development, a sample of this new ice was obtained with a coring auger. It was practically free of salt. At one locality, the layer had grown to a thickness of 20 cm by July 25. Here, the new ice was separated from the original ice bottom by 12 cm of fresh water. A constant temperature of −1.6°C was recorded in the ocean water beneath the new ice layer.

Manner of Formation of New Ice Layer: The layer of new ice appears to form as follows: Fresh surface melt water seeps through drain holes and pores in the pack ice, eventually accumulating at the ice bottom. There it floats on top of the cold, heavier ocean water. Fine, needle- and plate-like ice crystals develop between the fresh and salty water. These unattached crystals rise, gradually forming a loose, delicate fabric in the layer of fresh water, too tenuous to be felt when drilling. When these newly formed crystals can no longer rise, a solid layer begins to develop along the boundary between fresh and salt water, at the bottom of the network of fine crystals.

It was observed during August that this sub-layer of new ice, once formed, appeared to move upward while showing little increase in thickness. It seems unlikely that this rise was caused by buoyancy as it is assumed that the fine crystal network filling the fresh-water layer would be resistant to the buoyant force of ice forming along its lower margin. Probably, the rise of the top of the sub-layer actually results from freezing of the fresh-water layer, and the rise of its bottom surface represents melting of the fresh ice by the action of salty ocean water. The latter assumption is supported by the

observation that the ice continued to thin even after the fresh-water layer above it had completely frozen. This bottom ablation may end when surface cooling penetrates to the bottom of the ice pack.

The formation of this sub-layer of 20 cm of fresh ice by July 25 indicates unexpectedly rapid freezing. The growth of the sub-layer with time can be expressed by the equation—

$$s = -1 + (4 + 17t)^{1/2},$$

in which s = thickness in cm, and t = time in days. Under the ideal conditions implied in the formula, the thickness of the ice layer would increase from 1 cm to about 23 cm in 20 days. This agrees well with the observed increase. However, the formula neglects the possible ablation of the bottom of the sub-layer owing to the action of salt water; hence, it tends to give a maximum thickness. Moreover, if accumulations of fresh water under the pack ice were initiated during an interval of rapid ice drift (from June 17 to July 17 the average drift of the floe was 8 km/day) and turbulent mixing, a fresh-ice layer might not form at all.

Mass Budget: The formation of this sub-layer of fresh ice may be of basic significance in the mass budget of the ice pack.

Studies up to the present lead to the assumption that throughout the Arctic Basin sufficient heat is supplied during part of the summer to melt the recent snow cover as well as a certain amount of solid, or "old," ice. The thickness of the pack ceases to change when the annual accretion at the bottom of the ice is equal to summer ablation. Much of this bottom accretion may consist of the fresh-water ice. This possibility will be investigated further when studies of the salinity of pack ice are carried out.

Owing to continuing accretion at the bottom of ice of stationary thickness, it is assumed that there is an upward movement of mass within the ice pack. It should be expected, therefore, that on a very old, unbroken floe, the oldest ice lies immediately beneath the surface layer of new spring ice.

Thermal Budget

Data evaluation thus far permits only a few preliminary statements about the summer thermal budget. It is apparent that long-wave radiation is of great importance in surface melting. Throughout the observation period, melting occurred primarily when the sky was overcast and atmospheric radiation was strong. Freezing at the surface often accompanied short breaks in the overcast. Balloon soundings revealed frequent inversions in atmospheric temperatures, with comparatively high ceiling temperatures.

During melting, the pack-ice surface disintegrates into a loose layer of coarse, granular ice, which has a high albedo—higher than that of clean glacier ice. This may result from a difference in crystal structure and the penetration of radiation into the pack ice.

Temperature gradients in the layer of air just above the ice surface are usually very small or virtually lacking, according to measurements made 25, 50, and 100 cm above the ice. The humidity regime in this layer appears to be similar to the temperature regime. Direct measurements, made by weighing snow-filled pans, indicate that maximum evaporation occurred on June 29. A heat loss of 30 cal/cm^2 over a period of 12 hours was measured on this date. The maximum condensation, involving a heat gain of 16 cal/cm^2 in 12 hours, took place on September 14. Average heat gain is normally only several cal/day.

On the basis of observations made during the June–September 1957 period, it is expected that further data will show radiative heat to be the most important element in the summer thermal budget and in melting. The transfer of both sensible heat (heat released by turbulence or molecular conduction) and latent heat appear to be less significant.

Optical Tracking of Earth Satellites

This report was compiled from materials furnished by the Smithsonian Institution Astrophysical Observatory, Cambridge, Massachusetts, which directs the US-IGY optical tracking program. Reports on other satellite tracking programs may be found in *Bulletins 6* and *10* (volunteer visual and radio tracking), *2* (prime radio system), and *9* (volunteer photographic tracking).

Of the several satellite tracking programs designed for the IGY—radio, visual, and optical—it is the optical which is intended to obtain orbital and positional data of maximum precision. Once a satellite is located, or "acquired," by other means, and its orbit computed, precision optical tracking is accomplished by large tracking cameras. These tracking cameras cannot be used for acquisition because of their relatively restricted field. (The path of the satellite must first be known to within 3° of arc in order to aim the cameras.)

Baker-Nunn Tracking Camera

The precision camera designed for the US-IGY satellite tracking program is the Baker-Nunn camera, a modification of the Schmidt meteor camera.

Under optimum conditions, the Baker-Nunn tracking cameras will measure a satellite's position to an accuracy of two seconds of arc and $\frac{1}{1000}$ second in time. The camera is named for James G. Baker, who designed the optical system, and Joseph Nunn who designed the mounting, tube, drives, and other mechanical parts.

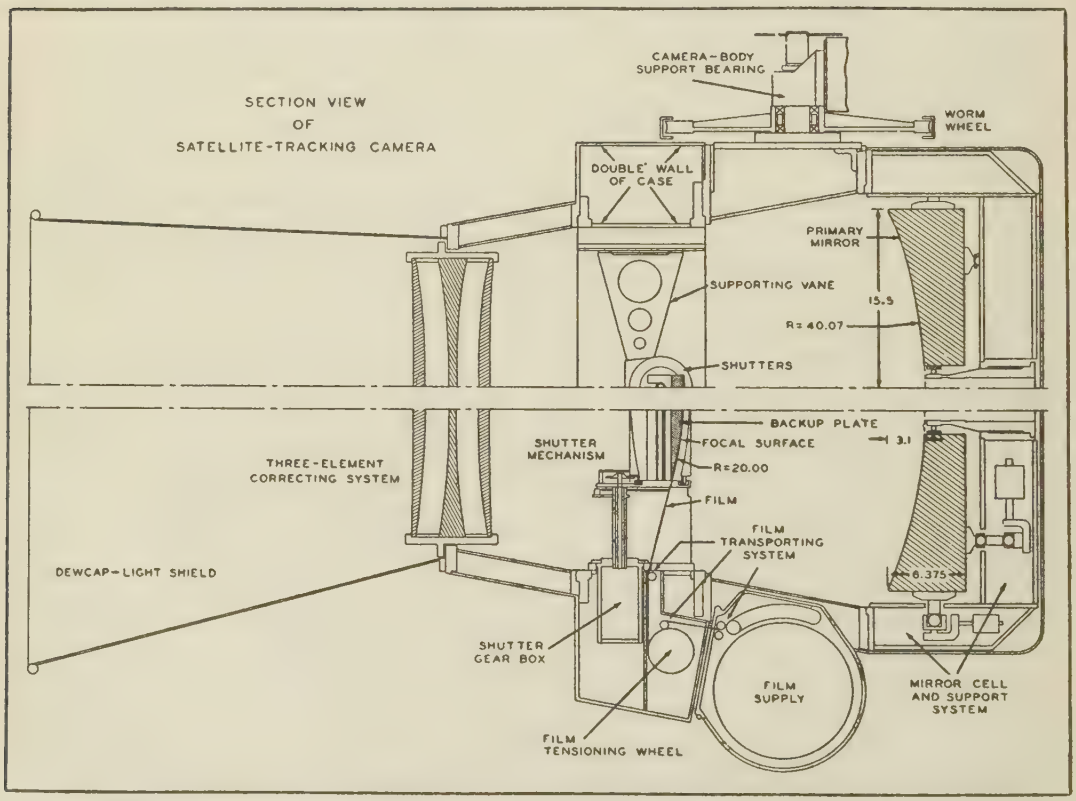

Fig. 11. *Two cross sections of the Baker-Nunn satellite-tracking camera, showing the film-transport and shutter mechanism. The two halves are at right angles to each other, and all dimensions are in inches. The double-walled camera case is in four sections (right to left), one holding the mirror, the next the support trunnions, the next the focal surface and film-transport system, and the last the three-element Schmidt correcting plate.*

Optical System: This camera utilizes a Schmidt optical system with a new type of correcting system. It has a focal length of 20 inches, an aperture of 20 inches (thus giving a focal ratio of f 1.0), and a field of 5° x 30°. The camera uses 55-mm Cinemascope film. Each photograph is about one foot long. The complete optical system is shown in Figure 11.

Camera Mounting: Use of a three-axis mounting permits the camera to track in any direction across the sky. For tracking, two axes are clamped in fixed positions and the camera body is rotated about the third axis by an electric drive.

TABLE 1

Angular Velocity (min of arc/sec)	*Limiting Magnitude*	
	Stationary	*Tracking*
87.8	5.8	10.8
42.1	6.6	11.6
19.4	7.4	12.4
8.9	8.3	13.3
0.25*	12.2	17.2

* This is the sidereal rate at the celestial equator. In this table, it is assumed that 80% of the light falls within a 30-micron circle. The satellite-tracking cameras in the US-IGY program exceed this efficiency.

Position Measurements: Traditional astronomical methods of measuring image positions relative to star images on the film are necessary in order to achieve the precision of two seconds of arc. When the satellite is tracked at maximum orbital velocity, the stars will trail and only those brighter than approximately 5.8 magnitude will be recorded. Usually, only two or three stars of this brightness can be expected to fall in the 5° x 30° field. If measurements must be made from the star image to the satellite image across several inches of film, stretching of the film and distortion of the emulsion will introduce greater errors than can be tolerated.

In order to avoid long measurements, the camera tracks alternately at the satellite rate and at the rate of sidereal (star) motion parallel to the satellite orbit. In this way exposures of both the satellite and the background of faint stars can be made on a single film. The satellite position is then measured relative to nearby star images. Satellite motion between the two exposures is compensated for by measuring the distance between the "star-exposure" images of the bright stars and the "satellite-exposure" images of these same stars. This distance will never exceed one inch, and the amount of film stretching over this distance will not introduce excessive error in the measurements.

A time reference is provided by using a rotating barrel-type shutter which causes sharp breaks in the trails of both the satellite and the bright stars. This shutter is shown in the upper part of Figure 11 as a cylinder enclosing the film back-up plate. Outside the barrel shutter is a "clamshell" shutter which opens and shuts to begin and end each exposure.

Tracking Cycle: For each film exposed, the camera automatically runs through a basic cycle that can be set at 2, 4, 8, 16, or 32 seconds. During this cycle, the tracking rate varies from sidereal to satellite and back again.

To begin the cycle, the clamshell shutter snaps open for an interval of 0.1 cycle, during which the exposure is chopped into four segments by the continuously rotating barrel shutter. At the instant of some one chop, a stroboscopic flash illuminates the time-display unit attached to the camera and the time is recorded photographically. After the clamshell closes, the tracking rate decelerates to the sidereal rate and the clamshell opens again for 0.1 cycle. This star exposure is likewise chopped into four segments, but the time is not recorded. After the shutter closes again, the film is automatically changed and the cycle repeats.

Effective Exposure: The setting of the mean tracking rate is continuously variable and in practice can be adjusted so that the camera tracks the satellite with an error of one percent or less. Tracking increases the effective exposure time by a factor of 100 over that possible if the camera remains stationary. This increase in effective expo-

TABLE 2

Station	Longitude	Latitude
Organ, New Mexico, U.S.A.	106°53′W	32°6′N
Olifantsfontein, South Africa	28°15′E	25°58′S
Woomera, Australia	136°48′E	31°08′S
Cadiz, Spain (Naval Obs., San Fernando)	6°12′W	36°28′N
Tokyo, Japan (Tokyo Astron. Obs., Mitaka)	139°33′E	35°40′N
Naini Tal, India (St. Uttar Pradesh State Obs.)	79°27′E	29°24′N
Arequipa, Peru	71°31′W	16°22′S
Shiraz, Iran	52°33′E	29°36′N
Curacao, N.W.I. (St. Barbara, Willemstad)	68°52′W	12°06′N
Hobe Sound, Florida, U.S.A. (Jonathan-Dickinson State Park)	80°7′W	27°01′N
Villa Dolores, Argentina	65°6′W	31°57′S
Haleakala, Maui, Hawaii	156°16′W	20°43′N

sure means that objects five magnitudes greater than otherwise possible can be photographed. Table 1 shows the limiting magnitudes for different tracking rates.

Time Measurement: The greatest possible angular velocity for a satellite in orbit is 5300 seconds of arc per second of time. Thus, a measuring accuracy of two seconds of arc in the direction of motion in this extreme case requires a determination of time to $\frac{1}{2500}$ second. Such accuracy cannot be maintained under field conditions but the time unit used on the camera does allow time measurements to $\frac{1}{1000}$ second.

The primary component of the time unit is a crystal clock. Added to this are a radio receiver for WWV time signals, a system of time presentation readable to $\frac{1}{10,000}$ second, and a "slave" clock that will duplicate the time presentation within the body of the telescope, where it can be photographed during each operating cycle of the camera.

The time presentation includes a rotating dial that indicates time to $\frac{1}{100}$ second, and an amplitude-modulated circular-sweep oscilloscope which can be read to $\frac{1}{10,000}$ second. This displays the output of the clock and compares it with the signal received from WWV. If daily comparisons with WWV are made, the error of this time system is held to $\frac{1}{1000}$ second.

Tracking Stations: The first Baker-Nunn Camera was installed at Organ, New Mexico, on November 15, 1957. Table 2 shows the location of all 12 precision photographic tracking stations of the US-IGY program.

Of the nine stations established outside United States territory, six are operated in cooperation with the IGY committee and other scientific organizations of the nations concerned. Australia, Japan, and India have assumed complete operating responsibility for their stations. Other countries have provided varying degrees of support in the form of personnel, sites, facilities, operating expenses, and communications. In addition to this extensive international cooperation, the optical tracking program has received valuable logistic and operational support from the US Air Force, Army, and Navy.

The locations were selected to give maximum coverage on satellites with orbits inclined at 35°–40° to the equator.

Through a special communications network, the Smithsonian Astrophysical Observatory provides each station with information on camera settings for each visible pass of each satellite. Each station develops the films as soon as possible, makes preliminary reductions of position data, and sends the information to the Astrophysical Observatory through the same communications net. The negatives are forwarded later for detailed analysis.

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Index to *IGY Bulletins 1–12*

Academy of Sciences, USSR 8: 18
Aerobee, Aerobee-Hi (See *Rockets*)
Agarwal, S. P. 11: 13
Airglow Measurements During the IGY 5: 4–6
Alaska, Gulf of 9: 12
Alaska Range 4: 15
Albedo, Snow and Ice 11: 4, 12: 13, 12:15
Alerts (See *World Days*)
Aleutian Trench 9: 13
Alidades (See *Aurora and Airglow*)
Allcock, G. Mck. 3: 12, 6: 7
All-sky cameras (See *Aurora and Airglow*)
Altiplano 11: 6, 11: 7
American Congress on Surveying and Mapping 9: 8
American Radio Relay League (ARRL) 6: 2
Anchorage, Alaska 6: 8
Andean Trench 7: 3
Anderson, K. A. 3: 6, 10: 9, 10: 10, 10: 12
Anderson, H. 11: 13
Anderson, Vernon 10: 4
Andes Mountains 1: 13, 8: 12, 10: 12, 11: 6
Annapolis, Maryland 6: 8
ANTARCTIC
Adare Station (later Hallett) 1: 7, Amundsen-Scott South Pole Station 1: 5, Animal migration 9: 10, Animal physiology 9: 10, Australian program 1: 15, Beardmore Glacier 10: 3, Botany studies 9: 10, Byrd Station 1: 5, Communications 1: 5, CSAGI Antarctic Regional Conferences 1: 4, 2: 11, 2: 14, Deep drilling program (See *Glaciology*), Deep Freeze I (1955–56) 1: 2, Deep Freeze II (1956–57) 1: 4, Deep Freeze III (1957–1958) 3: 4, Deep pit grogram (See *Glaciology*), Dentistry 9: 8, Ellsworth Station 1: 6, Geomagnetic pole station (Vostok II), USSR 10: 6, Gould Bay 10: 5, Human physiology 9: 9, Ice-fracture patterns, Ross Ice Shelf 10: 3, Islands, ice-covered, discovered on Ellsworth traverse 10: 5, Little America Station 1: 6, Liv Glacier 10: 3, Logistics 1: 2, Mountain range, unnamed (Byrd Traverse) 10: 4, Mountain range, new (Ellsworth Traverse) 10: 5, Mt. Hassage 10: 5, McMurdo Sound 10: 3, New Zealand symposium 11: 16, Nunataks 10: 4, Orientation program, Davisville, R. I., October 1956 1: 5, Penguin tracks (seen on Byrd traverse) 10: 4, Psychology 9: 9, Ross Ice Shelf 10: 2, Sea-ice studies 8: 10, Sentinel Mountains 10: 4, South Pole weather 5: 6–8, Sovietskaya Station, USSR 10: 6, Task Force 43, US Navy 1: 2, 8: 11, 10: 6, Trans-Antarctic Expedition, New Zealand-United Kingdom 10: 5, Traverse, airborne 10: 1, 10: 5, Byrd Station, 1957–58 1: 6, 10: 4, Ellsworth Station, 1957–58 1: 7, 10: 5, Little America Station, 1957–58 1: 6, 10: 2, to Byrd Station 2: 5, 8: 10, 10: 1, 10: 2, Oversnow 1: 6, 1: 7, 8: 10, 10: 1–7, Planned for 1958–59 10: 6, USSR, 1957–58 10: 6, US Program 1: 2–7, Weather Central 1: 2, 1: 6, 2: 2, 4: 7–10, 8: 9, 10: 1, Weather charts, synoptic 8: 9, Weather data 2: 2, 4: 7, Weather, South Pole 2: 14–15, Wilkes Station 1: 7
Antarctic Notes 2: 14
Antarctic Program 1: 2–7
Antofagasta, Chile 11: 7, 11: 8
ARCTIC
Arctic Ocean deep circulation 6: 12, deep water survey 4: 15, submarine ridges 6: 10–13, CSAGI Arctic Conference 2: 11, Drift ice stations 1: 7–9, Drifting Station A 1: 7, 6: 10–13, 8: 10, 12: 11, Drifting Station B 1: 7, 2: 4, Marine biology studies 9: 10, Rockoon firings in 5: 8–10, Sea-ice studies 1: 8, 2: 4, 8: 10, 9: 10, 12: 11–15, Thermal budget 1: 8, 2: 4, US program 4: 10–16, Weather buoys 1: 9
Arctic Drift Ice Station Program 1: 7–9
Arctic Ocean Submarine Ridges 6: 10–13
Arctic Program 4: 10–16
Arctic Sea-Ice Studies 12: 11–15
Army Signal Corps Radio Propagation Agency 3: 10
Army Signal Engineering Laboratories, US 11: 14
Arneb, USS 8: 7
Ascaugraph (See *Aurora & Airglow*)
Atka, USS 6: 6, 8: 7
Atofu 12: 6
Auger, coring 12: 14
AURORA AND AIRGLOW
Airglow programs—other countries 5: 4, Airglow program—US 3–14, 5: 4–6, Alidades, use of for auroral heights 12: 9, All-sky cameras 3: 13, Arctic Program in 4: 10, Arctic rockoon experiments 5: 8–10, Ascaugraph 3: 13, Auroral Data Center 12: 7, Auroral forms 12: 7–8, Auroral maps 8: 6, 12: 10, Aurora program—US 3: 13–14, Aurora, visual observation program 3: 13, 12: 6–11, Balloon experiments during aurora 10: 9, Drift motions, auroral 12: 9, Equinoctial periods, relation to auroral frequency 12: 8, Inclinometers, use of for auroral heights 12: 9, Isophotes, airglow 5: 4, 8: 6, Octants, use of for aurora heights 12: 9, Patrol spectrograph 3: 13, Photoelectric photometers for airglow studies 3: 14, Protons, auroral 10: 12, Radar program 3: 14, Riometer observations 3: 14, Rocket experiments 4: 5, 5: 10, Scanning spectrometers 3: 13, Simultaneity of auroras in northern and southern hemispheres 8: 6, Soft radiation and aurora 10: 9, 11: 11, Status and preliminary results, first five months of IGY, 8: 6, Theodolites, use of for auroral heights, 12: 9, VLF emissions and aurora 6: 9–10, Visual auroral observation program 3: 13, 12: 6–11, X-rays, auroral 10: 9–12
Aurora and Airglow Program 3: 13–14
Auroral Data Center (See *Aurora and Airglow*)
Bader, Henri 7: 5
Baird, Spencer F. 7: 4
Baker, J. G. 12: 17
Baker-Nunn tracking camera (See *Satellites*)
Ballistic Missile Agency, US Army 9: 1, 11: 15
Balloon experiments (See *Cosmic Rays*)
Bardin, I. P. 8: 18
Barkhausen 6: 5, 6: 6
Barrett, P. H. 3: 7
Barrow, Alaska 6: 10, 12: 12
Bartol Research Foundation 8: 19, 11: 13
Bathythermograph (See *Oceanography*)
Battle Creek, Michigan 6: 8
Beardmore Glacier 10: 3
Beaufort Sea 6: 12
Benedictson, Arni 6: 15
Benioff, Hugo 1: 13, 10: 12
Bering Strait 6: 11
Berkner, L. V. 5: 15
Bermuda 6: 8
Berning, W. W. 3: 15
Billings, D. 7: 15
Blagonravov, A. A. 5: 1, 5: 15
Blackouts, radio 8: 20
Blue Glacier 2: 4, 11: 1–5
Blue Glacier Studies 11: 1–5
Bottom photography (See *Oceanography*)
Boulder, Colorado 6: 8
Bowles, K. L. 3: 11
Bracewell, R. N. 7: 15
Bremsstrahlung (See *Cosmic Rays*)
British National Committee, IGY 8: 18
Brode, Robert 3: 4
Broggi, J. A. 10: 13
Bronk, D. W. 5: 15, 8: 18
Brown Bear 7: 2, 9: 11–13
Bulletin for Visual Observers of Satellites 6: 4
Bureau of Medicine and Surgery, US Navy 9: 9
Burkhardt, Louis 7: 15

Cahill, L. J., Jr., 11: 8
Calendar, IGY 2: 6, 5: 10
California Academy of Sciences 12: 2, 12: 4
California Institute of Technology 6: 2, 10: 12, 11: 1, 11: 4, 11: 15
Cambridge Research Center, USAF 6: 12, 11: 15
Canterbury University College, New Zealand 11: 9
Cape Canaveral, Florida 9: 1, 11: 13, 11: 15
Cape Horn, Argentina 6: 8
Capricorn Oceanographic Expedition, 7: 1
C^{14} method in dating of sea water 9: 11
Carnegie Andes expedition, 1957, 11: 6
Carnegie expedition, Rocky Mountains and Alaska, 1955 11: 6
Carnegie field party, Southwest US, 1954 11: 6
Central Radio Propagation Laboratory (CRPL) 3: 10, 6: 6, 7: 11, 12: 2, 12: 3
Cerenkov counter (See *Cosmic Rays*)
Chamberlain, J. W. 3: 13
Chasson, R. L. 3: 4
Chosica, Peru 10: 13
Chromosphere (See *Solar Activity*)
Chukchi Sea Peninsula 6: 11
Chuquicamata Mine 11: 7
Church, P. E. 11: 1
Cirque, glacial 11: 2, 11: 3
Coast and Geodetic Survey, US 9: 8, 11: 10
Cohen, R. S. 3: 11
College, Alaska 6: 8
Committee on Dentistry, National Academy of Sciences 9: 9
Comité Spécial de l'Année Géophysique Internationale (See *CSAGI*)
Compass Island, USS 8: 1
CONFERENCES
Antarctic Conference 2: 11, 2: 14, Boulder Conference on Ionospheric Studies Using Earth Satellites 7: 11–16 CSAGI, Antarctic Regional Conferences 1: 4, 2: 11, 2: 14, Arctic Conference 2: 11, Eastern Europe Conference 2: 11, New Zealand Antarctic Symposium 11: 16, South Africa Conference 2: 11, Western Hemisphere Conference 2: 11, Western Pacific Conference 2: 11, Rocket and Satellite Conference 5: 15–16, 6: 2
Constant tones 6: 9
Contacts (See *Solar Activity*)
COOPERATIVE PROGRAMS
Argentina 6: 8, Australia 6: 8, 12: 18, Canada 3: 16, 4: 4, 4: 10, 5: 8, 8: 7, Chile 10: 12–14, 11: 8, Iceland 6: 13–15, India 12: 18, Japan 12: 18, New Zealand 6: 8, 11: 9, Peru 10: 12–14, 11: 8, Sweden 1: 16, 8: 7, United Kingdom 6: 8, USSR 4: 8
Core, earth's 10: 13
Cornell University 12: 9
Corona (See *Solar Activity* and *Aurora and Airglow*, Auroral forms)
Coronagraph 12: 1, 12: 5
Cosmic-Ray Balloon Experiments 10: 9–12
Cosmic Ray Program 3: 3–7
COSMIC RAYS
Arctic program 4: 11, 5: 8–10, Balloon experiments 3: 5, 8: 7, 10: 9–12, 11: 13, Bremsstrahlung 10: 9, 10: 12, Cerenkov counter 3: 7, Emulsions, photographic 3: 5, Equator, cosmic ray 3: 4, 8: 7, Forbush decrease 11: 12, Geiger counter 1: 11, Ionization chambers 3: 5, 8: 7, 10: 9–10, 11: 12, Latitude effect on 3: 5, 3: 6, 8: 7, Latitude knee 3: 6, 11: 9, 11: 10, Meson intensity 11: 11, 11: 12, Meson telescope 3: 4, Multiple-coincidence shower detector 3: 7, Mu-meson studies 3: 7, Neutron-monitor studies 2: 15, 8: 19, 11: 12, Neutron-pile detector 8: 7, Photon counter 10: 9, Protons 11: 12, Quadruple-coincidence counter 11: 13, Rocket-borne experiments 4: 5, 10: 12, Rockoon experiments 5: 8–10, 10: 9, 11: 8–11, Satellite experiments 1: 11, 6: 16, 8: 16, Soft radiation 10: 9–11, 11: 11, Spectrometer, magnetic-electron 5: 10, Status and preliminary results, first five months of IGY 8: 7, Sweden-USA cooperative program 1: 16, US program 3: 3–7, Variations in intensity 11: 11–13, Vertical-counter telescope 10: 10, 10: 11
CO_2 in atmosphere 2: 4, 7: 3
CO_2 in ocean 7: 3
Crary, A. P. 1: 5, 10: 3
Crevasse detectors 10: 7
Crichlow, W. Q. 3: 12
Cruise of the Brown Bear 9: 11–13
Crust, earth's 11: 6
Crystal clock (See *Satellites*)
CSAGI (Comité Spécial de l'Année Géophysique Internationale) 1: 15, 2: 11–14
CSAGI conferences (See *Conferences*)
CSAGI And The International Geophysical Year 2: 11–14
CSAGI Rocket and Satellite Conference 5: 15–16
Current Sunspot Numbers 4: 1–3
Curtis, H. W. 6: 7
DAN (See *Rockets*, Nike-Deacon)
Danger Islands (Pukapuka) 12: 2, 12: 4
Danjon astrolabe (See *Latitude and Longitude*)
Dartmouth College 6: 6, 6: 7, 6: 8
DATA CENTERS
Auroral Data Center 12: 7, Data processing 8: 12, Meteorological Data Center 7: 9, 7: 11, World Data Centers 2: 12–13, 5: 15, 8: 12
Davidson, Maurice J. 1: 8, 6: 12
Davies, D. A. 7: 9
Dawn chorus 3: 12, 6: 9
Day, Sir Archibald 1: 15
de Bey, L. G. 7: 15
Deep current program (See *Oceanography*)
Deep drilling program (See *Glaciology*)
Deep-water studies (See *Oceanography*)
Denver Research Institute, University of Denver 3: 9
Department of Terrestrial Magnetism, Carnegie Institution of Washington 3: 9, 8: 12
Dickson, F. R. 7: 15
Discovery II 8: 10
Donn, W. L. 9: 14
Doppler effect 7: 13, 7: 15, 10: 16
DOVAP (DOppler-Velocity-And-Position) 4: 5
Downwind Oceanographic Expedition 7: 1
D-region (See *Ionospheric Physics*)
Drifting stations (See *Arctic*)
Dufek, George 1: 5, 10: 6
Duller, N. M. 3: 7
Dunedin, New Zealand 6: 8
Earth Satellite Program, The 1: 9–12
Earth Strain Measurements in South America 10: 12–14
Easter Island Rise 7: 3
Eckersley dispersion law 6: 8
Eclipse, solar 12: 1–6
Eklund, C. R. 1: 5, 9: 10
Electrojet 8: 5, 11: 10
Electrokinetograph, geomagnetic (GEK) (See *Geomagnetism*)
Ellesmere Island 6: 11
Ellsworth Station, Antarctica 6: 8
Elvey, C. T. 3: 13
Emulsions, photographic (See *Cosmic Rays*)
Eötvös correction 8: 3
Equator, celestial 12: 17
Equator, cosmic-ray 8: 7
Equator, geomagnetic 8: 5
Equinoctial periods 12: 8
E-region (See *Ionospheric Physics*)
Extensometer (crustal-strain seismograph) (See *Seismology*)
Fadeouts, radio 7: 7, 8: 6
Falling sphere experiment (See *Rockets*)
Faraday effect 7: 14
Federal Observatory, Zurich 4: 1
Firn (See *Glaciology*)
First Sea Surface Gravimeter 8: 1–4
First US-IGY Satellite 9: 1–3
Fisher, R. L. 7: 2
Flares, solar (See *Solar Activity*)
Fletcher, J. O. 1: 8
Fletcher's Ice Island (Drifting Station B) 1: 7, 2: 4
Floats, neutrally buoyant (See *Oceanography*)
Forbush decrease (See *Cosmic Rays*)
Forbush, S. E. 3: 9
FOREIGN PROGRAMS
Airglow programs 5: 4, Australia 1: 15, Canada 6: 8, Japan 6: 8, 12: 6, New Zealand 10: 5, 11: 16, 12: 6, Reports from other countries 1: 15, 11: 16, United King-

dom 1: 16, 10: 5, USSR 2: 13, 5: 1–3, 6: 8, 6: 15–16, 10: 6, 12: 6
Fort Churchill, Canada 4: 4, 4: 7, 10: 10
Fraunhofer spectrum (See *Solar Activity*)
Friedlander, M. 3: 7
Friedman, Herbert 3: 15, 7: 7
Frobisher Bay, NWT 6: 8
Fuchs, V. E. 10: 6
Fysiska Institutionen, Upsala, Sweden 8: 20

Gainesville, Florida 6: 8
Gallet, R. M. 6: 9, 7: 14, 8: 6
Gartlein, C. W. 3: 13, 12: 6
Gassmann, G. F. 3: 10
Gauges, erosion (See *Satellites*)
Geiger counter 1: 11, 3: 6, 4: 5, 8: 16, 10: 9
Geological Survey, US 9: 8
GEOMAGNETISM
Arctic program in 4: 12, Antarctic program in 10: 3, 10: 4 Electrokinetograph, geomagnetic (GEK) 7: 1, Equator, geomagnetic 8: 5, Electrojet, equatorial 8: 5, 11: 10, Geomagnetic storms 11: 12, Magnetic charts, US Navy Hydrographic Office 11: 11, Magnetic measurements 11: 10, 11: 11, 12: 7, 12: 8, Magnetic observatories, in US 3: 9, in Pacific 3: 9, 11: 10, Magnetograph, differential 3: 9, Magnetometer, proton precession 3: 16, 11: 10; Magnetometer, rocket-borne 11: 10, 11: 11, North pole, geomagnetic 11: 12, Poles, geomagnetic 12: 7, Poles, magnetic 8: 5, Rocket-borne experiments in 4: 5, Satellite experiments in 1: 12, Status and preliminary results, first five months of IGY 8: 5, Upper atmosphere electric currents 3: 8, 8: 5, US Program 3: 7–10, 8: 5, Variometers 11: 10
Geomagnetism Program 3: 7–10
Geophysical Institute, University of Alaska 3: 13, 3: 14
Giacobini-Zinner comet 5: 2
Giesecke, Albert Jr. 3: 9
Glacial structures 11: 5
Glacier, USS 11: 8
GLACIOLOGY
Albedo studies 11: 4, Arctic Program in 4: 15, Blue Glacier 2: 4, 11: 1–5, Cirque 11: 2, Cores, ice 8: 10, Deep drilling program 2: 5, 4: 15, 7: 5, 7: 6, 8: 9, Deep pit program 2: 5, 7: 5, 7: 6, Drill holes, Ross Ice Shelf traverse 10: 3, Firn 11: 3, Firn limit 11: 4, Hinge cracks, Ross Ice Shelf 10: 3, Ice fabrics 11: 5, Ice-fracture patterns, Ross Ice Shelf 10: 3, Ice temperature probe 11: 4, Inclinometer surveys 11: 5, Krakatoa, dust from in ice 8: 10, Lemon Glacier 2: 4, McCall Glacier 2: 4, Moraines 11: 5, Mass budget studies, Arctic 12: 15, Movement stakes 11: 2, 11: 3, 11: 5, Needle crystals 11: 3, 12: 14, Oxygen isotope studies 11: 4, Pit studies on Antarctic traverses 10: 3, 10: 4, Pit studies on Blue Glacier 11: 5, Polar ice and snow studies 7: 5–6, Radiometers 11: 4, Ramsonde measurements, Antarctic traverses 10: 3, 10: 4, Rime 11: 4, Sea-ice-atmosphere heat exchange 2: 4, Sea-ice physics 2: 4, 8: 10, Seismic-wave velocity in ice 11: 5, Settlement gauge, snow 11: 3, Snow density 11: 3, Status and preliminary results, first five months of IGY 8: 9, Structures, glacial 11: 5, Thermocouples, use for ice temperatures 11: 4, US program 2: 4–5, Winter chill in firn 11: 4
Goddard, Robert 4: 4
Goldstein, Norman 1: 8
Gottlieb, M. B. 10: 9
Graf, Anton 8: 1, 8: 12
Grammer, George 7: 15
Gravimeter (See *Gravity*)
GRAVITY
Arctic program in 4: 15, Gravimeter measurements 1: 14, 8: 1–4, Little America Station, studies at 10: 3, Pendulum measurements 1: 14, Pendulums, submarine-borne 8: 1, Satellite experiments 1: 11, Sea surface gravimeter (Graf) 8: 1–4, 8: 12, US program 8: 1, 1: 14
Greenland, ice and snow studies 7: 5–6
Grenade experiment (See *Rockets*)
Grindavik, Iceland 6: 14
Gulf Stream, deep currents in (See *Oceanography*)
Gyro-compass 10: 7

Halifax, Canada 6: 8
Hanover, New Hampshire 6: 8
Haute Provence Observatory, France 5: 6
Hayden, E. 7: 15
Heat, latent 12: 11
Heat, radiative 12: 11
Heat, sensible 12: 15
Helliwell, R. A. 3: 12, 6: 8
Herbstreit, J. 7: 15
High Altitude Observatory, University of Colorado 7: 9, 12: 2, 12: 5
Hillary, Sir Edmund 10: 6
Himalayas 11: 6
Hiss 3: 12, 6: 9
Horizon 7: 1, 7: 4
Huancayo Geophysical Observatory, Peru 1: 13, 6: 8
Hubley, R. C. 4: 15

Ice fabrics 11: 5
Ice-fracture patterns, Ross Ice Shelf (See *Antarctica*)
Ice hummocks 12: 14
IGY Antarctic Oversnow Traverses 10: 1–7
IGY Antarctic Weather Central 4: 7–10
IGY News from Other Countries 11: 16
IGY Research Rocket Program, The 4: 4–7
IGY Satellite Program Notes 8: 18–19
Inclinometers 11: 5, 12: 9
Inflatable sphere (See *Satellites*)
Interferometers, total-power 7: 14
International Flare Patrol 3: 2, 4: 3
Inversions (See *Meteorology*, Temperature inversions)
Ionization chambers 3: 5, 4: 5, 8: 7, 11: 12
IONOSPHERIC PHYSICS
Arctic program in 4: 11, Backscatter stations 3: 11, Blackout, radio (polar) 8: 8, D-region 7: 7, 8: 8, E-region 4: 5, Fadeouts, radio 8: 6, "Ghosts," half-transit 7: 14, Ionospheric drift 3: 10, Pulse experiment 3: 11, Radio hams 3: 11, 7: 15, Radio noise 4: 12, 4: 14, 8: 6, Riometer observations 3: 14, 4: 11, Recorder, airborne 3: 10, Rocket-borne experiments in 4: 5, Satellite studies 1: 11, 7: 11–16, Sounders 6: 6, Sounders, sweep frequency 3: 10, Soundings, vertical incidence 8: 6, 12: 4, South Pole Station 1: 5, 8: 7, Sporadic E 3: 11, Status and preliminary results, first five months of IGY 8: 6, Sudden Ionospheric Disturbances (SID) 7: 7, Sudden Phase Anomalies (SPA) 7: 7, Transequatorial scatter studies 3: 11, Traveling wave tube principle 8: 6, US program 3: 10–12, Very low frequency (VLF) phenomena 3: 12, 4: 12, 6: 5–10, 8: 6
Ionospheric Physics Program 3: 10–12
Ionospheric Studies Using Earth Satellites 7: 11–16
Isabella, California 10: 12, 10: 14
Island observatory program 9: 14
Isophotes (See *Aurora and Airglow*)
Isostasy 11: 6

Jackson, J. E. 3: 15
Jastrow, R. 7: 15
Jean, A. G. 6: 6
Jet Propulsion Laboratory, California Institute of Technology 6: 2, 9: 1, 10: 15
Johnson, C. Y. 3: 16
Jones, L. M. 3: 15
Jordan, A. R. 3: 9

Kaplan, Joseph 8: 18
Kaplon, M. F. 3: 6
Katmai 7: 6
Kellogg, P. J. 10: 12
Kimball, D. S. 12: 6
Klengur 6: 15
Knob Lake, Quebec 6: 8
Korff, S. A. 3: 4, 3: 6
Kotzebue, Alaska 3: 9, 4: 10, 6: 8
Krakatoa 7: 6, 8: 10
Krasnaya Pakhra Observatory, USSR 2: 7, 8: 5
Krasovsky, Valerian 5: 2

La Gow, H. E. 3: 15
Lamont Geological Observatory 1: 13, 2: 3, 6: 12, 8: 1, 9: 14
LATITUDE AND LONGITUDE
Danjon astrolabe 1: 15, Moon-

LATITUDE AND LONGITUDE—*Continued*
position camera 1: 15, Satellite experiments 1: 11, US program 1: 14–15
Latitude effect (See *Cosmic Rays*)
Latitude knee (See *Cosmic Rays*)
Lawrence, R. S. 7: 15
Lemon Glacier 2: 4, 4: 15
Life Sciences in the IGY 9: 8–10
Line Islands 3: 9, 11: 8, 11: 10
Little, C. G. 3: 10, 7: 15
Liv Glacier 1: 6, 10: 3
Llano, G. A. 9: 10
Loki II (See *Rockets*)
Lommaren 1: 16, 8: 7
Lomnitz, Cinna 10: 13
Lomonosov Ridge 4: 16, 6: 11
Lord, J. J. 3: 5
Ludwig, G. H. 8: 13, 11: 15
Lyman-alpha radiation (See *Solar Activity*)
Lyman-alpha satellite (See *Satellites*)
McCall Glacier 2: 4, 4: 15
MacDonald, W. S. 7: 15
McMurdo Sound 1: 2, 1: 3, 1: 5, 4: 8, 10: 3
Macquarie Island 1: 15, 6: 8
Maeda, K. 6: 8
Magnetism (See *Geomagnetism*)
Magnetometers (See *Geomagnetism*)
Manring, E. R. 5: 4
Mantle, earth's 10: 13, 11: 6, 11: 7, 11: 8
Maple, Elwood 3: 9
Marine biology, Arctic (See *Arctic*)
Marine biology, on *Brown Bear* cruise 9: 12
Markowitz, William 1: 15
Matthews, Whitney 8: 13
Meadows, Edith 3: 16
Meinesz, Vening 8: 1
Menard, H. W., Jr. 7: 2
Meredith, L. H. 10: 9
Meson (See *Cosmic Rays*)
METEOROLOGY
Antarctic (See *Antarctic*), Arctic program in 4: 14, Blue Glacier studies in 11: 1–5, Cloud cover experiment—earth satellite 1: 12, CO_2 in atmosphere 2: 4, 7: 3, 8: 9, Data Center (See *Data Centers*), Microbarovariograph 6: 13, 6: 14, 6: 15, 9: 14–16, Microbarograph 6: 13, 6: 14, Microcard program 7: 9–11, Ozone studies 4: 14, 8: 9, Pressure variations, long-period 9: 15, Radiometer 11: 4, 12: 12, Radiosonde observations 4: 8, 7: 10, Rawinsonde observations 2: 2, 4: 8, 4: 14, 7: 10, Rime 11: 4, Sea-ice-atmosphere heat exchange 1: 8, 2: 1, 2: 4, 12: 11, South American stations 2: 2, South Pole weather 2: 2, 2: 14, 5: 6–8, Status and preliminary results, first five months of IGY 8: 9, Synoptic surface observations 2: 2, 7: 10, Temperature inversions 2: 15, 5: 7, 12: 15, Turbulence short-period 9: 15, Upper wind observations 7: 10, US program 2: 1–3, Weather charts, synoptic 1: 6, 2: 2, 4: 8, 8: 9, World Meteorological Organization (WMO) 7: 9, World Weather Map 4: 8, Weather buoys (See *Arctic*)
Microbarograph (See *Meteorology*)
Microbarovariograph (See *Meteorology*)
Microbarovariograph: A New Instrument for Measuring Minute Atmosphere Pressure Variations, The 9: 14–16
Microcard Program for IGY Meteorological Data 7: 9–11
Microlock (See *Satellites*)
Microseisms (See *Seismology*)
Midpac Oceanographic Expedition 7: 1
Minitrack (See *Satellites*)
Mont Joli, Quebec 6: 8
Moonbeam (See *Satellites*)
Moon, in solar eclipse 12: 1, 12: 3
Moon-position camera (See *Latitude & Longitude*)
Moonwatch (See *Satellites*)
Moonwatch Observing Methods 6: 4–5
Moraines, glacial 11: 5
Morgan, M. G. 3: 11, 3: 12, 6: 6, 6: 8, 6: 9
Motu Koe 12: 3, 12: 4
Mount Olympus 11: 2
Mount Wilson Observatory 7: 9, 8: 5
Movement stakes (See *Glaciology*)
Mu mesons (See *Cosmic Rays*)
Nanda, J. N. 7: 3
Nansen bottle (See *Oceanography*)
National Academy of Sciences, US 1: 1, 8: 18
National Advisory Committee for Aeronautics 1: 12
National Institution of Oceanography, England 1: 13, 2: 3, 8: 10
National Research Council of Canada 8: 20
Naval Radiological Defense Laboratory 12: 2, 12: 4
Naval Research Laboratory 1: 9, 1: 12, 6: 2, 6: 16, 7: 7, 8: 14, 11: 13, 12: 2, 12: 4
Neher, H. V. 3: 5, 11: 12
Nelson, J. H. 3: 9
Nesmeyanov, A. N. 8: 19
Neutron (See *Cosmic Rays*)
New Siberian Islands 6: 12
New Zealand Dominion Physical Laboratory 6: 7
New Zealand National Committee for IGY 11: 16
Ney, E. P. 3: 6, 10: 9
Nike-Cajun (See *Rockets*)
Nike-Deacon (DAN) (See *Rockets*)
North Pacific (See *Oceanography*)
North Pole, geomagnetic 11: 12
Novosibirskiye Ostrova (New Siberian Islands) 6: 11
Nunataks 10: 4
Nunn, Joseph 12: 17
Observatories, island (See *Oceanography*)
Oceanographic Expedition Downwind 7: 1–4
Oceanographic Island Observatory in Iceland 6: 13–15
OCEANOGRAPHY (See also *Arctic, Antarctic*)
Aleutian Trench 9: 13, Bathythermograph 7: 3, Bathythermograms 9: 12, Bottom photography 7: 3, *Brown Bear* cruise 9: 11–13, C^{14} method of dating sea water 9: 11, Currents, North Pacific 9: 11–13, Deep-water studies 2: 3, 4: 15, 7: 1, 8: 10, 9: 11, Downwind Expedition 7: 1–4, Eel larvae, leptocephalus stage (*Brown Bear* cruise) 9: 13, Floats, neutrally buoyant 2: 3, 8: 10, Great Britain 2: 3, Gulf Stream 8: 10, Heat flow probe (for bottom sediments) 7: 3, Island observatories 2: 3, 4: 15, 6: 13–15, 9: 14, Marine biology 8: 11, 9: 8, 9: 12, Microbarovariograph 9: 14–16, Nansen bottle 7: 1, 7: 3, Oxygen in ocean water 2: 4, 8: 10, 9: 13, Recorder, long-period waves 9: 15, Salinity 9: 13, Sea level 6: 13, Seamounts 7: 3, Sea swell 6: 14, Seiches 6: 14, Seismic refraction profiles 7: 3, Status and preliminary results, first five months of IGY 8: 10, Surges, storm 9: 14, Temperature 9: 13, Tide gauge studies 6: 13–15, 8: 11, Tsunami 9: 15, US program 2: 3–4, Wave meters 6: 14, Wildlife observations, *Brown Bear* cruise 9: 13
Odishaw, Hugh 1: 1, 5: 15, 8: 5, 8: 19
Office of Naval Research 11: 10
Oliver, N. J. 3: 13
Olympic Mountains 11: 1
Optical Tracking of Earth Satellites 12: 16–18
Oxygen, sea water (See *Oceanography*)
Oxygen isotopes in snow 7: 5, 11: 4
Ozone (See *Meteorology*)
Pace, Nello 9: 9
Paquette, R. G. 9: 11
Pendulum measurements (See *Gravity*)
Peruvian National Committee for IGY 10: 12
Pennsylvania State University 3: 10
Peterson, A. M. 3: 11
Peterson, L. 10: 9, 10: 12
Pfister, Wolfgang 3: 12
Photography, ocean bottom (See *Oceanography*)
Photometers, recording 5: 4
Photon counters 4: 5
Phototrack 9: 3–8
Pit studies (See *Glaciology*)
Plages, solar (See *Solar Activity*)
Plato, James 5: 2
Pobedonostsev, Y. A. 5: 1
Polar Ice and Snow Studies 7: 5–6
Pole of inaccessibility (Antarctic) 10: 6
Pole of inaccessibility (Arctic) 6: 12
Poles, magnetic (See *Geomagnetism*)
Pomerantz, M. A. 3: 4, 3: 5, 8: 19, 11: 13
Potnis, V. R. 11: 13

Preliminary Report on Rockoon Firings in the Arctic 5: 8–10
Preliminary Summary of USSR Satellite Reports 5: 1–3
Probe, heat flow (See *Oceanography*)
Probe, ice temperature (See *Glaciology*)
Prominences, solar (See *Solar Activity*)
Protons (See *Cosmic Rays*)
Protons, auroral (See *Aurora and Airglow*)
Pukapuka (See *Danger Islands*)
Quadruple-coincidence counter (See *Cosmic Rays*)
Quinault, Washington 11: 2
QST, American Radio Relay League Journal 6: 2, 8: 18
Radiometers 11: 4, 12: 12
Radio tracking (See *Satellites*)
Ramsonde (See *Glaciology*)
Rawinsonde observations (*See Meteorology*)
Regener, V. H. 3: 7
Regular World Days (See *World Days*)
Reports from Other Countries 1: 15–16
Report on the United States Program, A 8: 5–13
Riometer 3: 14, 4: 11
Riverhead, L. I. 6: 16
Roach, F. E. 3: 14, 5: 4
Roberts, W. O. 7: 15
Rocket Flare Patrol Program 7: 7–9
ROCKETS
Aerobee 4: 4, Aerobee-H i 4: 4, Airglow experiments in 4: 5, Aurora experiments in 4: 5, Cosmic ray experiments in 4: 5, 10: 9, 10: 12, CSAGI Conference on Rockets and Satellites 5: 15–16, 6: 2, Falling sphere experiment 3: 15, Flare patrol program 7: 7–9, 8: 8, Geomagnetism experiments in 3: 16, 4: 5, Grenade experiments in 3: 15, Hawk rockoon vehicle 11: 9, Ionospheric physics experiments in 3: 14–16, 4: 5, Jupiter-C series 8: 9, 9: 1, 11: 15, Loki II, in rockoon combination 11: 9, Meteorological experiments in 4: 5, Nike-Asp 12: 4, Nike-Cajun 4: 4, Nike-Deacon (DAN) 4: 4, 7: 7–9, Pre-IGY program 3: 15, 4: 6–7, 8: 7, Rockoons 3: 15, 4: 4, 4: 6, 4: 7, 5: 8–10, 10: 9, 11: 8–11, Satellite rocketry 1: 9, Solar activity experiments in 4: 5, 7: 7–9, 12: 1–6, Status and preliminary results, first five months of IGY 8: 7, Telemetry systems 12: 4, United Kingdom program 1: 16, US program 3: 14–16, 4: 4–7, USSR program 2: 13–14, Vanguard series 8: 9
Rocket Program 3: 14–16
Rockets & Satellites: Radio Tracking System, 2: 7–11
Rockoon (See *Rockets*)
Rockoon Flights in the Atlantic, Pacific, and Antarctic Areas 11: 8–11
Ronne, Finn 1: 5, 10: 5
Rose, D. C. 3: 6, 8: 20
Rosario, L. del 3: 7
Ross Ice Shelf, Antarctica 1: 3, 10: 2, 10: 3
Sacramento Peak Observatory 7: 9, 12: 2, 12: 5
San Cristobal, Chile 10: 13
Sandström, A. E. 3: 4, 8: 20
San Marcos University, Peru 11: 6
San Nicolas Island 7: 7, 12: 4
Santiago, Chile 10: 13, 12: 3
Saskatoon, Canada 6: 8
SATELLITES
Air density experiments 1: 11, Baker-Nunn tracking camera 1: 10, 9: 3, 12: 16, Batteries, solar, 1958 Beta 11: 14, Cloud cover experiments 1: 12, Cosmic ray experiments 1: 11–12, 8: 16, 9: 1, 11: 15, Crystal clock, use in tracking camera 12: 18, CSAGI Rocket and Satellite Conference 5: 15–16, Earth energy balance measurement 1: 12, Earth's mass distribution 1: 11, Gauges, erosion 8: 15, 8: 16, 9: 1, Geodetic determinations 1: 11, Inflatable sphere experiment 1: 12, Interferometer principle, in tracking 2: 8–9, 10: 15, Ionospheric studies 1: 11, 7: 11–16, Ionization chamber in 8: 14, Jupiter-C, launching vehicle 8: 9, 9: 1, 11: 15, Lyman-Alpha experiments in 8: 14, Magnetic field experiments 1: 12, Memory devices in satellite telemetry 8: 13, 11: 15, Meteor detectors 1: 12, 8: 15, 11: 15, Microlock 2: 11, 6: 2, 9: 2, 10: 15, 10: 16, Micrometeorite experiments in 1: 12, 8: 15, 9: 1, 11: 15, Minitrack 1: 10, 2: 7–10, 6: 2, 8: 17, 9: 2, 11: 15, Minitrack Mark II 2: 11, 6: 2, 10: 15, Moonbeam 6: 1–2, 9: 5, 10: 15, 10: 16, Moonwatch 6: 1, 6: 4–5 6: 16, 9: 2, 9: 5, Optical tracking of 1: 10, 6: 2, 12: 16–18, Picket fence 6: 2, Photographic tracking of 6: 3, 9: 3–8, 12: 16, Phototrack 9: 3–8, Radio amateurs, observations by 6: 1–2, 7: 15, 9: 5, 10: 15, 10: 16, Radio tracking 1: 10, 2: 7, 6: 1–2, Rocketry 1: 9, 8: 9, 9: 1, Schmidt meteor cameras 12: 16, Solar aspect cells in 8: 15, Solar ultraviolet experiments 1: 11, Status and preliminary results, first five months of IGY 8: 8, Telecameras 12: 17, Telemetry 6: 1–2, 8: 13–18, US 1958 Alpha 9: 1–3, 10: 15, 16, US 1958 Beta 11: 13–15, US 1958 Gamma 11: 15–16, US program 1: 9–12, USSR 1957 Alpha 5: 1–3, 8: 8, USSR 1957 Beta 6: 15–16, 8: 8, USSR, exchange of notes with 8: 18–19 USSR program 2: 13–14, USSR visual observation program 6: 1, Vanguard Computing Center 10: 15, Vanguard series 8: 9, 11: 13, Visual observation program (See *Moonwatch*), Volunteer Observers 6: 1–2, Volunteer photographic tracking 6: 3, 9: 3–8, Volunteer radio observations 6: 2, 10: 15–16, Volunteer telemetry recording 6: 2, 8: 18, Yeast experiment 9: 8
Satellite Telemetry 8: 13–18
Schmidt meteor camera (See *Satellites*)
Schork, L. L. 8: 1
Scintillation counters 4: 5, 10: 9
Scripps Institution of Oceanography 1: 13, 7: 1, 11: 10
Sea-ice studies (See *Arctic, Antarctic*)
Seamounts (See *Oceanography*)
Sea swell (See *Oceanography*)
Seattle, Washington 6: 6, 6: 8
Second and Third US-IGY Satellites 11: 13–16
Second Soviet Satellite 6: 15–16
Seddon, J. C. 3: 15
Seismic refraction profiles, oceanographic (See *Oceanography*)
Seismic Studies in the Andes 11: 6–8
SEISMOLOGY (See also *Arctic, Antarctic*)
Andes, studies in 11: 6–8, Compressional waves 10: 14, 11: 6, Extensometer (crustal-strain seismograph) 1: 13, 10: 12–14, Love waves 10: 14, M-discontinuity 11: 6, 11: 7, 11: 8, Mantle velocities 11: 8, Microseisms 1: 13, Mongolian earthquake, December 4, 1957 10: 14, Pacific seismic installations 8: 12, Rayleigh waves 10: 14, Refraction profiles, oceanographic 7: 1, Seismographs, long-period 8: 12, Seismometers, standard 10: 12, Shear waves 10: 14, Status and preliminary results, first five months of IGY 8: 11–12, Strains, secular (long-range) 10:13, Strains, tidal (diurnal) 10: 13, Ultra-long-period-waves 10: 13, US program, status report 1: 13, Wave velocity in ice 11: 5
Seismometer, strain (See *Extensometer*), standard 10: 12
Sentinel Mountains (See *Antarctic*)
Settlement gauge, snow 11: 3
Sferics 3: 12, 6: 6
Shapley, A. H. 7: 11
Sharp, R. P. 11: 1
Shear, J. A. 1: 5
Shelikof Strait, currents in 9: 12
Shadow bands 12: 5
Signal Corps Engineering Laboratories 1: 12
Signal Corps, US Army 8: 19
Sigurdson, Petur 6: 15
Simpson, J. A. 3: 4
Siple, P. A. 1: 5
Siri, William 9: 9
Sky and Telescope 6: 4
Skyhook balloon program 3: 5
Slichter, L. B. 1: 14
Smithsonian Astrophysical Observatory 6: 4, 8: 19, 12: 16, 12: 18

Snow, Ice, and Permafrost Research Establishment (SIPRE), US Army 7: 5, 8: 9
Snowdome (See *Blue Glacier*)
Society of Photographic Scientists and Engineers (SPSE) 9: 3, 9: 8
Soft radiation 5: 10, 8: 7, 10: 9–12
SOLAR ACTIVITY
Arctic program in 4: 13, Chromosphere 12: 1, Contacts, in solar eclipse 12: 3, Corona, solar 8: 6, 12: 1, 12: 5, Coronagraph 12: 1, 12: 5, Eclipse, October 12, 1958, 12: 1–6, Flares 3: 2, 4: 3, 10: 7, 11: 12, Flash spectrum 12: 5, Fraunhofer spectrum 12: 5, Interferometry 12: 4, Lyman-alpha radiation 12: 4, Magnetic field, solar 8: 5, Moon, in solar eclipse 12: 1, 12: 3, Photomultiplier 12: 4, Plages 4: 3, Prominences 4: 3, Radio noise stations 3: 2, Recorder, oscillograph 12: 5, Rocket-borne experiments in 4: 5, 12: 1–6, Satellite studies 1: 11, 6: 16, Solar spectrum 12: 1, 12: 5, Spectrographs, radio-frequency 3: 2, Status and preliminary results, first five months of IGY 8: 5, Sunspots 8: 5, 10: 7, 12: 1, Sunspot numbers 4: 1–3, 11: 12, 12: 1, US program 3: 2–3, US-IGY Technical Panel on 12: 1, X-rays, simulation experiments 10: 11, X-rays, solar 8: 5, 10: 10, 12: 4
Solar Activity Program 3: 2–3
Solar batteries, 1958 Beta 11: 14
Solarimeters 12: 12
South American meteorological stations (See *Meteorology*)
South Pole Winter Weather Review 5: 6–8
Special Committee for the IGY (See *CSAGI*)
Special World Day Program for the IGY, The 5: 10–14
Spectrographs, patrol 3: 13
Spectrographs, radio-frequency 3: 2
Spectrographs, rocket-borne 4: 5
Spectrometer, magnetic electron 5: 10, mass 3: 16, scanning 3: 13
Spectrum, solar (See *Solar Activity*)
Spencer, N. W. 3: 15
Sporadic E (See *Ionospheric Physics*)
Spruce-Quinault area, Washington 11: 2
Stanford University 6: 6, 6: 8
State University of Iowa 1: 12, 5: 8, 10: 11, 11: 8, 11: 10, 11: 15
Status Report: Meteorology, Oceanography, & Glaciology 2: 1–5
Status Report: Seismology, Gravity and Latitude & Longitude 1: 13–15
Status Report: The Upper Atmosphere Program 3: 1–16
Stevenson, E. C. 3: 10
Storey, L. R. O. 3: 12, 6: 6
Submarines, gravity measurements from 8: 1
Sunfollowers, rocket-borne 4: 5
Sunspots (See *Solar Activity*)
Suwarrow Island 12: 6
Svalbard 6: 12
Swallow, J. C. 8: 10
Swann, W. F. G. 3: 5
Task Force 43, US Navy 1: 2, 1: 3, 2: 15, 10: 6, 11: 9
Taylor, R. C. 5: 6
Telecameras (See *Satellites*)
Telemetry (See *Satellites; Rockets*)
Theodolites (See *Aurora and Airglow*)
Thorareuson, Benedict 6: 15
Thorlakshofn, Iceland 6: 14–15
Thermograph 6: 14
Thiel, E. C. 10: 5
Thomaston, USS 12: 3
Thule, Greenland 6: 8, 8: 19
Thule Neutron Monitor Station 8: 19–20
Tide gauge studies (See *Oceanography*)
Toney, G. R. 1: 5
Topchiev, (Academician) 8: 19
Toquepala Mine 11: 7
Total Solar Eclipse: October 12, 1958 12: 1–6
Tousey, Richard 3: 15
Transequatorial scatter (See *Ionospheric Physics*)
Traverse (See *Antarctic*)
Tritium, in snow 7: 5
Tsunami waves (See *Oceanography*)
Tuamotu Archipelago 7: 3
Tusk, USS 8: 2
Tweeks 6: 8
Tyr, (Icelandic Survey Vessel) 6: 15
Unalaska, Alaska 6: 7, 6: 8
University of Chicago 3: 13, 8: 7
University of Chile 10: 12, 11: 6
University of Manchester 8: 6
University of Minnesota 10: 12
University of Washington 7: 2, 9: 11, 11: 1, 11: 2, 12: 11
University of Wisconsin 12: 2, 12: 4
Untersteiner, Norbert 12: 11
Upper wind observations (See *Meteorology*)
Van Allen, J. A. 3: 16, 5: 8, 10: 9, 10: 12, 11: 8, 11: 15
Vanguard Computing Center 10: 15
Vanguard Control Center 11: 15
Variations in Cosmic Ray Intensity 11: 11–13
Variometers 11: 10
Viets, R. L. 11: 16
Villard, O. G. 3: 12
Visual Auroral Program, The 12: 6–11
Volunteer observers, auroral (See *Aurora and Airglow*)
Volunteer Participation in the IGY Earth Satellite Program 6: 1–3
Volunteer Satellite Tracking by Radio 10: 15–16
Waldmeier, M. 4: 2
Wallop's Island, Virginia 8: 7
Walter Reed Army Medical Center 9: 10
Waynick, A. H. 3: 10
Weasel oversnow vehicle 10: 6
Weather at the South Pole 2: 14–15
Weather buoys 1: 9
Wellington, New Zealand 6: 8, 11: 16
Wells, H. W. 7: 14
Whistlers and Related Phenomena 6: 5–10
Wiewall, Miguel 3: 10
Winckler, J. R. 3: 6, 10: 9, 10: 12
Woods Hole Oceanographic Institution 1: 13, 2: 4, 8: 10
Woollard, G. P. 1: 14
World Data Centers (See *Data Centers*)
WORLD DAYS
Alerts 5: 11, 8: 5, 10: 7, 12: 8, Associate Warning Centers 5: 12, International program 2: 5–7, Regional Warning Centers 5: 12, Regular World Days 5: 10, Special World Days 5: 10, 12: 10, Special World Intervals 2: 7, 5: 10, 8: 5, 12: 8, 12: 10, US program 5: 10–14, Whistler program 6: 8, World Meteorological Intervals 2: 5, 5: 10, World Warning Agency 2: 7, 8: 5, 9: 5, 12: 8, World Warning Agency Decisions, October 3, 1957–January 1, 1958 10: 7–8, World Warning Centers 10: 8, World Warning Messages, June 28–October 2, 1957 5: 14
World Days During IGY 2: 5–7
World Meteorological Intervals (See *World Days*)
World Warning Agency (See *World Days*)
World Warning Agency Decisions, October 3, 1957–January 1, 1958 10: 7–8
World Warning Centers 10: 8
World Weather Map 4: 8
Worzel, J. L. 8: 1, 8: 12
WWV (radio station) 5: 12, 6: 3, 9: 6, 9: 7, 12: 18
X-Rays (See *Solar Activity*)
Yagoda, Herman 3: 5
Yerkes Observatory 3: 13, 12: 4
Young, O. B. 3: 5
Ziegler, H. K. 11: 14